Rockfish Removals in Alaska Sport Fisheries 1977 through 2023

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# Abstract

Fishery stock assessments require defensible estimates of total extractions (commercial, sport, subsistence, personal use, and bycatch) throughout the history of exploitation and at appropriate spatial scales for management. This study provides updated estimates of total sport harvest and releases for black and yelloweye rockfishes as well as demersal shelf, slope and non-black pelagic rockfish in southeast, in geographic units consistent with commercial fishery management units (CFMUs), such that total fishing mortality could be estimated. Estimates were originally produced in Howard et al. (2020) covering the period between 1999 and today and the Bayesian methods used here allow for estimations back through 1977, correct faulty assumptions in the Howard methodology, and correct for survey bias. Sport harvest and release information is available from Alaska Department of Fish and Game saltwater guide logbooks and the Alaska Sport Fishing Survey (commonly known as the statewide harvest survey or SWHS). Guide logbooks have provided a census of guided sport harvest and release by statistical reporting areas and by pelagic and nonpelagic rockfish assemblages since 1998/1999, and a census of yelloweye rockfish harvest and release since 2006. The SWHS has provided estimates of harvest and catch by guided and unguided anglers, but at a coarser geographic scale, and not by species or assemblages (e.g., pelagic–nonpelagic) of rockfish. Port sampling data provides estimates of species composition in the harvest as well as length and weight data. The bayesian model used here calculates harvests very similar to the methods used in Howard et al. (2020) but differs in how releases are estimated. Bias in the SWHS harvest and release numbers are corrected in the model and the Bayesian model does not make the Howard et al. (2020) assumption that the species composition of the harvest is equal to that of the released fish. The Bayesian model also uses a hierarchical approach such that information is more appropriately shared across areas within regions and more appropriately propogates error. Assumptions about key parameters and estimates before data collection began are made using logistic curves to estimate trends. Harvest estimates from the Bayesian model are very similar to the Howard et al. (2020) estimates but release estimates differ considerably as a result of bias correction and more informed estimates of release probability by species and species assemblage as evident in the logbook data. Sport black and yelloweye rockfishes harvests and releases provided by this methodology are recommended for use in stock assessments of these species statewide, and the methodology could be useful for other marine finfish species where stock assessment models are needed.

Keywords: sport fish, harvest, release, fishing mortality, black rockfish, yelloweye rockfish, demersal shelf rockfish, slope rockfish, pelagic rockfish, Gulf of Alaska, *Sebastes*, *Sebastes melanops*, *Sebastes ruberrimus*, rockfish

# Introduction

Rockfish (*Sebastes spp*) harvests in Alaskan waters have become an increasing concern as restrictions on halibut and salmon has led to increased pressure on rockfish stocks. In response to this pressure, the Alaska Department of Fish and Game (ADF&G) initiated an interdivisional, inter-regional strategic plan to develop long-term management and stock assessment strategies for black rockfish (*S. melanops*) and yelloweye rockfish (*S. ruberrimus*) across the Gulf of Alaska (GOA) (Howard et al. 2019a). The first step in assessing any fish stock is to have an accurate and complete history of fishery removals from the stock. While commercial fisheries relies on a fish ticketing system that censuses the harvest, Alaska sport fisheries rely on a number of programs, phased in over time, to account for rockfish removals in the sport fishery.

Sport fishery harvests are measured through a variety of programs, primarily the Alaska Sport Fishing Survey (commonly known as the statewide harvest survey or SWHS), the saltwater guide logbook program, and sampling programs at primary ports. The SWHS was initiated in 1977 as an annual mail-out survey (Romberg et al. 2018). Response to this survey is voluntary and the survey design provides for estimates of statewide harvest and catch (since 1990) in numbers of fish for rockfish (all species combined) and effort in saltwater angler days (for all marine species combined) by unguided and guided anglers (since 2011) and by predefined geographical strata. These SWHS strata are not, however, geographically consistent with either sport rockfish fishery management areas or commercial fisheries management units (CFMUs). Because of these factors, additional data sources are necessary to estimate black and yelloweye rockfish harvests from consistent, spatially explicit areas. The guided logbook program was established in 1998 to acquire information on guided industry harvests and releases by species and effort (Powers 2015). In addition to other species such as salmon and halibut, this mandatory program provides a census of harvest and release in numbers of pelagic and nonpelagic rockfish species assemblages and, since 2006, yelloweye rockfishes. The logbook program also provides information on the statistical area where fishing occurred. Sport harvest port sampling programs provide information on biological characteristics of the harvest, including species composition (Jaenicke et al. 2019; Failor 2016). Port sampling programs vary regionally in their design, history, and information collected. The estimation of release mortalities in commercial and sport fisheries presents additional challenges for understanding total fishing mortality. The ability to estimate total removals by both sport and commercial fisheries will enable assessment of harvest rates and be useful for future stock assessments.

Yelloweye and black rockfish removal estimation methods were originally developed by Howard et al. (2020; hereafter refered to as the Howard methods), which included spatial partitioning of the data, identifying bias in the SWHS survey estimates relative to the logbook census of guided anglers, and estimating unguided harvests and releases by expanding logbook catch and release data using the proportions of guided:unguided harvests and releases from SWHS data. This approach was both novel and critical in providing harvest and release estimates for managers to understand the magnitude of the catch and to allow accurate assessments of stocks.

While the Howard methods provide the baseline for understanding and reconstructing rockfish harvests in Alaska, the methods had several shortcomings and recommendations for reevaluation as more data and improved methodologies become available. The Howard methods were limited to the period since the logbook program was brought online in 1998 and thus only provides estimates since that time even though rockfish have been harvested by sport anglers since the 1960s or earlier. The methods also rely on a “decision tree” approach to deal with missing data by using long term averages or proxy values from neighboring management areas. Furthermore, while the Howard methods address bias in the SWHS data, it is not implicitly estimated or corrected and, whats more, ignores potential differences in the bias of harvest and release data. Lastly, the estimates of releases are also based on an assumption that the species composition of released fish is the same as that of the harvest, despite clear differences in the harvest and release patterns present in the logbook data.

The methods presented here build on the foundational Howard methods by applying a Bayesian approach to expand the harvest and release time series back to 1977 when the SWHS was first implemented, estimating and correcting bias in the SWHS harvest and release data, allowing release probabilities to vary by species / species assemblage, and replace the decision tree approach with a hierachichal model that more accurately and efficiently shares information between areas within regions (Table X). The Bayesian model estimates trends in species proportions and harvest/release probability to project backwards in time while explicitly estimating bias in the SWHS harvest and release data (Figure X). Furthermore, the model’s hierarchichal structure allows information on these trends, as well as overall harvest trends, to be shared among management areas within the three main regions (Southeast, Southcentral and Kodiak) without having to use proxy values and more effectively propagates error throughout the process. The model incorporates fish weight and release mortality probabilities (CITATION) so that previously unpublished total removal estimates in biomass are also produced in one place. These methods provide a more streamlined and reproducible approach to deriving rockfish removal estimates.

# Objective

1. Estimate annual sport harvests,releases and total removals in biomass of rockfishes in Gulf of Alaska CFMUs from 1977–2023. Southcentral and Kodiak CFMUs include estimates for black and yelloweye rockfish while Southeast CFMU’s include estimates of black, yelloweye, non-black pelagic (dark *S. ciliates*, dusky *S. variabilis*, widow *entomelas*, yellowtail *S. flavidus*, and blue *S. mystinus* rockfish), non-yelloweye demersal shelf (canary *S. pinniger*, quillback *S. maliger*, china *S. nebulosus*, copper *S. caurinus*, rosethorn *S. helvomaculatus* and tiger *S. nigrocinctus* rockfish), and slope rockfish (redbanded *S. babcocki* , rougheye *S. aleutianus*, silvergray *S. brevispinis*, shortraker *S. borealis*, and vermillion *S. miniatus* rockfish).

# Study Area

Reconstructions were developed for CFMUs across the Gulf of Alaska, from Kodiak Island east to Southeast Alaska (Figures XX). Small amounts of black and yelloweye rockfishes harvest also occurs in the South Alaska Peninsula, Chignik, and Bering Sea/Aleutian Island areas; however, harvests and releases in these areas are too small to be accurately estimated with current sampling programs, and no port sampling programs exist in these areas to allow for estimates of black and yelloweye rockfish specifically.

# Methods

## Data

Statewide harvest survey estimates of rockfish catch and harvest are available for 28 years (1996-2023) for all users and for 13 years (2011-2023) for guided anglers (Figure X). Additionally, there are overall harvest estimates from 1977- 1995 and release estimates from 1990-1995 that required some partitioning to ascribe to current management units. Harvests in unknown areas were apportioned based on harvest proportions in 1996. Variance estimates are not available for pre-1996 data and as such, the maximum observed coefficient of variation (cv) in each commercial fisheries management unit was applied to the pre-1996 values. SWHS Rockfish release estimates are inferred from the difference between catch and harvest estimates and variances calculated accordingly.

SWHS estimates of harvests and releases are assumed to be biased based on the disagreement between SWHS estimates of guided trips and matching logbook totals of guided harvests and releases (Figure DATA BIAS). Additionally, the bias in harvests and releases varies considerably (Figure DATA BIAS). The model treats the logbook data as a census with minimal uncertainty and thus SWHS bias estimation is a product of the difference between the survey and the logbook data.

Sport fishing guides have been required to report their harvest of rockfish for 26 years (1998-2023). Reported harvest is also available by assemblage (pelagic vs. non-pelagic). Harvest of yelloweye and “other” (non-pelagic, non-yelloweye) rockfish were reported separately beginning in 2006. Logbook data is treated as a census of the true catch and release of rockfish in these categories.

Harvest sampling data exists from Gulf of Alaska areas since 1996 and from Southeast Alaska areas since 2006 (CITATIONS?). Port sampling data is comprised of the number of total rockfish, pelagic and non-pelagic rockfish, black rockfish and yelloweye rockfish. In Southeast Alaska, the number of Demersal Shelf Rockfish (DSR, of which yelloweye are one species) and slope rockfish are also recorded.

*WEIGHT DATA FROM WHERE?* chris and Clay

*RELEASE MORTALITY DATA FROM WHERE?* Chris, Clay. Insert depth methods here.

Annual release mortality estimates in Southcentral and Kodiak were then calculated by averaging the the mortality-at-depth estimates weighted by the estimated proportion released at depth.

*KODIAK HYDROACOUSTIC HERE* Port sampling for outlying areas in Kodiak are unavailable to inform species compositions and thus are largely reliant on the hierarchichal structure of the model to derive estimates from the sampled areas. However, ADF&G commercial fisheries division has a robust hydroacoustic survey around the island to estimate black rockfish abundance and as part of that survey estimates species compositions of the pelagic rockfish communities in this area (CITATION). This was used as supplemental data to further inform the species composition in the Kodiak CFMUs.

## Process equations

The true harvest of rockfish for area during year is assumed to follow a temporal trend defined by a penalized spline:

where in a p-spline basis with 7 components (knots) and a second degree penalty. The variance, , was given a normal prior with a mean and standard deviation of 0.25 and 1, respectively (Table PRIORS1).

Harvests were apportioned by user groups such that charter and private harvest (where *u* = 1 for charter anglers and *u* = 2 for private anglers) is a fraction of total annual harvest in each area:

where is the fraction of the annual harvest in each area taken by charter anglers. was modeled hierarchically across years as:

with non-informative priors on both parameters (Table PRIORS1).

Annual black rockfish harvest for each area and user group is:

where is the fraction of the annual harvest for each area and user group that was pelagic rockfish and is the fraction of the annual harvest of pelagic rockfish for each area and user group that was black rockfish.

The southeast region also tracks two other non-pelagic rockfish assemblages, demersal shelf rockfish (DSR, which includes yelloweye) and slope rockfish. For the southeast region the harvest of those two assemblages is thus

where and are the fractions of the annual harvest of non-pelagic rockfish for each area and user group that were DSR and slope rockfish, respectively.

Annual yelloweye rockfish harvest for each area and user group is calculated differently for central/Kodiak areas and southeast areas. For central and Kodiak areas yelloweye rockfish harvests are calculated as

where is the fraction of the annual harvest of non-pelagic rockfish for each area and user group that was yelloweye rockfish.

For southeast areas yelloweye harvests are a fraction of the DSR harvests such that

Species composition data is not available for the entire time series and as such it was necessary to assume some trend in the data to project backwards in time. To do so, we fit a logistic curve to the species composition data that would account for shifts in the species composition during the observed time period but would not extrapolate beyond the limits of the observed data when hindcasting. Thus, tThe composition parameters , were modeled using a logistic curve such that:

where the parameters define the intercept, scaling factor, slope, inflection point and private angler effect, respectively, is the year index, is an index variable which is 1 when the user groups is private and 0 otherwise and is a random effect with a non-informative prior. parameters were modeled hierarchically by region. When parameters were inestimable as a result of no discernible change in composition over the observed time period. (scaling factor) and (slope) were fixed to 0 so that the long term mean value was used for hindcasting (Table pH\_PRIORS).

The true number of released rockfish were based on the proportion of the total catch harvested, , by area, year, user group and species grouping. Because release data from the SWHS is for all rockfish and the release data from logbooks is only subdivided into pelagics, yelloweye and “other” (non-pelagic, non-yelloweye), we only estimated for those categories. Thus, converting to total catches by user group, , with results in estimates of total releases such that

with total releases equal to the sum of the compositional releases. For non-yelloweye DSR and Slope rockfish assemblages in Southeast Alaska and were estimated from using the species composition data from the harvest, thus assuming that slope and DSR assemblages were caught and released at the same rates.

The proportion harvest parameters for were modeled using a logistic curve that would allow hindcasting based on trends in the data without extrapolating beyond the range of observed values such that

A random effect term allowed estimation during the historical period when data is available, but the curve defined by the above equation determined release estimates between 1977 and 1990. As with the compositional trends, parameters were modeled hierarchically by region. When parameters were inestimable as a result of no discernable change in harvest probability over the observed time period, (scaling factor) and (slope) were fixed to 0 so that the long term mean value was applied.

It was assumed that was equal to given the dominance of that species within the assemblage. For southeast Alaska, there was no way to estimate or and so and were applied to the estimates to generate estimates of and . The assumption that DSR and slope rockfish would be released in similar proportions was deemed reasonable given that these species tend to be caught fishing similar habitat and methods and these species are regarded similarly by anglers.

Estimating the proportion of slope rockfish in the releases required adding a fifth term to equation LOGITSPECIESCOMP to account for yelloweye being included separately. This term offset the overall logit curve to differentiate in the harvests and releases.

Release mortality (i.e., the number of released rockfish expected to die) was calculated assuming fixed mortality rates developed in each of the regions. Deep water release (DWR) devices were mandated for charter fleets in 2013 and rates were derived from CITATION. Southeast applies basic rates estimated in these studies while Southcentral and Kodiak rates were derived by using historical depth-of-release data to adjust the rates based on area and user group (FIGURE DWR).

The total number of mortalities by year, area, user and species/species assemblage in numbers was calculated by summing harvests and release mortality such that

where is the release mortality rate by year, area, user and species (Figure XX).

Total removals in biomass were converted using the average weight of fish **from port sampling?**. A minimum sample size per year of **X** fish was used as the cutoff for including in the data set. Weights were modeled hierarchically to estimate weights in years when data was missing. The total biomass of removals by year, area, user and species was thus

where is the mean weight by species, area, user and year.

## Observation equations

The process model was fit to the SWHS, logbook and port sampling data using the following equations. SWHS estimates of annual rockfish **harvest** were assumed to index true harvest:

where bias in the SWHS harvest estimates is modeled hierarchically across years as:

with non-informative priors on both parameters (Table PRIORS). SWHS estimates of guided angler harvest are thus related to total harvest by:

Reported guide logbook harvest are considered a census of the true harvest and is related to true harvest as:

Note that for central and Kodiak areas is equal to the total harvest minus pelagic and yelloweye harvests. For southeast areas is equal to the sum of the DSR and slope harvests *minus* yelloweye harvests.

SWHS estimates of annual rockfish **releases** were assumed to index true releases similarly to harvests and were modeled such that:

SWHS estimates of guided angler release is modeled the same as harvests, but assumed a different bias such that

where bias in the SWHS release estimates is modeled hierarchically across years as:

with non-informative priors on both parameters.

The number of pelagic rockfish sampled in harvest sampling programs follow a binomial distribution:

where is the total number of rockfish sampled in area during year form user group . The number of black rockfish sampled in harvest sampling programs was thus a proportion of the pelagic harvests

Yelloweye rockfish in Southcentral and Kodiak were modeled similarly as a proportion of the total number of non-pelagics such that

Southeast areas have several other non-pelagic groupings such that DSR and slope rockfish are a proportion of non-pelagics

and

with yelloweye in southeast a proportion of the DSR harvest

Kodiak has limited port sampling beyond the main harbors but has a robust hydroacoustic survey that is used to quantify black rockfish abundance across the management area and uses stereocameras to derive species compositions of the hydroacoustic data. This data was used as supplementary data to further inform the model to the proportion of pelagic rockfish that are black in Kodiak areas. Where angler landing data is available, they demonstrate a higher proportion of black rockfish relative to the hydroacoustic survey and thus the proportion of black rockfish in the hydroacoustic sample related to the true proportion such that

where is the angler effect for each area and user group modeled hierarchically around a mean of 0. Predicted assumed a beta distribution such that

where

where is the coefficient of variation for the hydroacoustic proportions

and the variance is approximated using the delta method (CITATION) as

where and are the variance of the estimated number of black and pelagic rockfish in the hydroacoustic survey, respectively (CITATION).

The average weight of rockfish by species, user, area and year was modeled hierarchically at several levels within regions such that

where *region* refers to Kodiak, Southcentral and Southeast. Mean weights and variance were calculated as **XXX**.

## Priors

Priors used in this model ranged from uninformative to very informative. We chose loose priors whereever possible, but the logistic curves used to hindcast the and required fairly informative priors to achieve convergence in the model (Table PRIORs, PRIORs, PRIORs). Prior development began with the most uninformative options and were tightened during model development to achieve convergence and the produce reasonable logistic curves based on the data.

Many of the parameters and priors are modeled hierarchically across regions and / or years. The penalized spline used to fit the overall harvest models the lambda terms hierarchically by region while the model assumes a single standard deviation for the random effects of the species composition logistic curve. The standard deviation of the random effect of the proportion harvested was modeled hierarchically by species. The beta terms in the and curves were also modeled hierarchically by region such that all CFMU’s within the same region share the same hyperprior for those terms.

It is also work noting a particularly restrictive prior used on the terms that describe the offset of the pH logistic curve for unguided anglers (Table pH\_PRIOR). The only information on unguided releases is the biases and inprecise estimate for all rockfish from the SWHS. To generate an estimate for unguided anglers required an assumption that harvest patterns of unguided anglers generally followed those of guided anglers fairly closely and as such the prior for the terms is very informative to maintain reasonable estimates of unguided releases with manageable credibility intervals.

## Model platform and diagnostics

The model was run using JAGS version 4.3.1 using the jagsUI and rjags packages (Plummer et al. 2006, Lunn et al. 2009, Plummer 2024) on the statistical R Statistical Software (v4.4.3;R Core Team 2021). Model convergence was judged by examining traceplots and ensuring that Rhat values were below 1.1 (Gelman and Rubin 1992).

# Results

The estimation model was able to estimate harvests, releases and total removals (harvests plus release mortalities) with near complete convergence of model parameters. Harvest estimates were very similar to Howard et al. (2020) estimates, but differed more in areas where private anglers were the dominant user group. Release estimates were also very similar to guided estimates from the Howard estimates which is not surprising given that both methods rely on the census derived from the logbook program. Estimate of unguided releases for black rockfish were generally substantially lower than the Howard methods, although the Bayesian credibility intervals frequently overlapped with the Howard estimates. The large change is to be expected given the bias correction undertaken in the Bayesian model and the more appropriate use of the proportion harvested data from the logbook program. Yelloweye release estimates also differed from the Howard estimates for private anglers although the direction of the difference varied by CFMU.

Explanation of unconverged parameters:

1. Spikyness and parameters near 0 / bounds.
2. BSAI and SOKO2SAPs
3. beta terms when difficult to fit logistic curves.

## Model Fit

## Bias Estimation

Model predicted bias in SWHS harvest data tracked the observed bias well across years and CFMUs (Figure YEARAREA\_BIAS) and demonstrated that SWHS estimates were generally biased low (Figure MEAN\_BIAS). The model tracked release bias well across years and CFMUs but generally smoothed the more variable observed SWHS bias (Figure YEARAREA\_BIAS). This is likely the result of far less precision in the SWHS release estimates. The overall bias in SWHS release estimates showed much more variability and in contrast to harvest estimates, generally showed the SWHS to overestimate releases (Figure MEAN\_BIAS).

## Proportion Harvested

Estimates of the proportion harvested (pH) for guided pelagic rockfish accurately tracked the logbook data and the logistic curve fit to that data demonstrated reasonable patterns and uncertainty for hindcasting in the model (Figure pH\_PEL). All CFMUs demonstrated a similar pattern where retention of pelagic rockfish has increased since the logbook program began in 1998, with very few black rockfish being released in recent years.

The proportion harvested for unguided anglers was assumed to track the same patterns as guided anglers, which the model captures satisfactorily. Given the lack of data specific to unguided releases other than the SWHS estimates for all rockfish the confidence intervals around unguided pH of unguided anglers were appropriatelly large. Instances where pH of guided and unguided anglers diverge were the result of the model’s balancing of all the data such that the sum of rockfish releases in each area match the bias corrected SWHS estimates of total releases.

The proportion harvested of yelloweye rockfish demonstrated a very different pattern from pelagics whereby guided anglers have retained almost all landed fish until recent years when management restrictions came into effect (Figure pH\_YE). This is most obvious in the Southeast CFMU’s where yelloweye retention was prohibited beginning in 2020 and to a lesser degree in Prince William Sound (CFMU PWSI and PWSO) where restrictions also came into effect.The model tracked this data well and the hindcasting logistic curve tracks the high retention probablitiy back in time.

The proportion harvested of unguided yelloweye rockfish was generally estimated to be lower than for guided anglers across CFMUs, but captures the same dynamic as guided anglers and reflects management restrictions that have come into play in recent years. As expected, credibility intervals for unguided anglers were significantly larger and usually included guided angler estimates.

For non-pelagic / non-yelloweye rockfish () the proportion harvested demonstrated variable patterns across regions (Figure pH\_OTHER). Central regions demonstrated a static pattern with the exception of Cook Inlet where retention probabilities increased over the course of observed time periods. Kodiak demonstrated increasing retention probabilities with the exception of the WKMA CFMUs which were static. In contrast, Southeat CFMU’s show a pattern similar to that of yelloweye rockfish with very high retention until management restrictions came into effect in recent years. As with the pelagic and yelloweye categories, unguided proportion harvested tracked the guided estimates as model design intended.

## Species Composition

The species composition of the harvests tracked the observated data well and produced reasonable logistic curves for hindcasting. The Pelagic proportion demonstrated either an increasing trend in the harvests (Southeast and Prince William Sound) or a static trend (Kodiak, Cook Inlet and North Gulf)(Figure P\_PEL). Model estimates tracked the observed data well and fell towards the trend line when sample sizes were small or absent. The logistic hindcasting curve appeared to match the trends in the data and encompass the uncertainty derived from the random effect estimates. The term had a much less informative prior than applied to terms but nevertheless resulted in fairly minor differences between guided and unguided anglers with the exception of PWSI and, to a lesser extent, SSEI.

The proportion of pelagic rockfish that were black proved to be static, with the exception Cook Inlet, which showed an increase) and NSEI, which showed a descrease (Figre P\_BLACK). The model tracked observed values well and applied the uncertainty derived from the random effects in the hindcast values. Applying the hydroacoustic survey data to Kodiak proved to be both informative and useful in estimating those values. Without that data the estimates tended toward the hyperprior values as informed by the Northeast data and resulted in credibility intervals that stretched from 0 to 1. The hydroacoustic data clearly demonstrates higher black rockfish proportions in these other areas and the model was able to generate far more precise and more realistic estimates of these parameters.

## Proportion Guided

Data on the proportion of total rockfish catches that were guided is lacking and there was no trend estimated for hindcasting these parameters. The model captured the observed estimates within the credibility intervals, but tended to smooth the observed estimates to some degree (Figure pG). Without a modeled trend, the model essentially uses a long-term average as described by the estimated beta distribution of the pG parameters to hindcast and appears to capture the uncertainty occurring in observed periods.

## Weight and Release Mortality

## Harvest, Release and Total Removal Estimates

# Discussion

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