Comparison of data filtering methods for indices of abundance from a recreational fishery survey

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Abstract

This is the abstract.

It consists of two paragraphs.

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1. Introduction

Fisheries stock assessments rely on a wide range of data to model a fishery's population dynamics. Catch data is a primary input to stock assessments and informs the overall magnitude of the stock. Catch data are often input with the assumption that the removals are known with absolute precision, i.e., there is no error associated with removals. A secondary data stream is an index of abundance that provides information on the size of the population. An absolute index of abundance is a census of a fish stock that is oftentimes input as a single year due to the high cost associated with determining total fish abundance within an area (include example).

More often, an index of abundance is a relative measure of the population over time and requires a time series, of four to five years at a minimum. Fisheries survey and catch data are used to develop standardized indices of abundance that inform fisheries stock assessment models (**?**).Fishery-independent data collected from standardized survey designs provide are preferred when creating an index of abundance to represent the trend in a fisheries population. Fishery-independent surveys. . . .. However, fishery-independent surveys are costly, labor intensive and often require a long time series to be considered informative in fisheries stock assessments.

When fishery-independent data are not available, assessors try to make best used of the best available data, which may often only include fishery-dependent data.

There are both advantages and disadvantages that must be considered when using to fishery-dependent data. Fishery-dependent data are collected directly from the the fishery and are less costly than the whose operations are not constrained by sampling designs, but dependent on the behaviors of the captain and vessel and, in the case of recreational trips, customer preference.

Fishery-dependent data are only collected from areas legally open areas can be collected, i.e., areas closed to fishing are not sampled. In California, this includes a network of marine protected areas (MPAs), rockfish conservation areas (RCAs) developed based on depth closures, and varying seasonal and depth closures that vary temporally and spatially along California's coastline. Fishery-independent surveys are conducted using a scientific study design and, depending on the study, are not always confined to the same

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regulations as the commercial and recreational fishing sectors. In an ideal situation, both fishery-dependent and fishery-independent surveys would used to inform the stock assessment model.

Catch per unit effort (CPUE) is a common metric collected from fishery-dependent or fishery-independent surveys, with the latter providing unbiased data. Depending on the stock assessment model and the available data for a particular fish stock, an index of stock status can have a large influence on end year estimation of stock status (find examples).

An index of relative abundance assumes that changes in the index are proportional to changes of abundance in the population (**?**).

Fishery-dependent surveys sample the fishing fleets and are subject to potential sampling biases. The sampling is dependent on the fishing boat's behavior, which is to maximize catch. Sampling of the fishing fleet is often opportunistic based on the availability of samplers and the availability of trips to sample. Sampling the fisheries can also be constrained to the current regulations, which may prohibit the retention of a species or fishing at certain depths, i.e., California Department of Fish and Wildlife has varying spatial and temporal depth and season closures implemented through six management regions. There is also a fairly new network of Marine Protected Areas (MPAs) designated from 2007-2012 that prohibit recreational fishing, and are therefore areas no longer sampled by the recreational fishing fleet. However, the advantage to fishery-dependent sampling the reduced program cost compared to a more intensive fishery-independent survey.

This data series evaluated in this analysis is part of the onboard observer program, which collects location- and species-specific CPUE information for the recreational fishing fleet (Monk et al. 2014)

The Pacific Fishery Management Council manages groundfish off the West Coast of the United States under the Groundfish Fishery Management Plan (FMP). The FMP includes 64 species of rockfish, _____ of which do not have full stock assessments. Many of these species, especially those nearshore, are assessed using multiple assessment models to represent areas with distinct fishing histories, communities regulations. Along the U.S. West Coast, even if the stock assessment is categorized as data rich, oftentimes the only index of abundance available is from a fishery-dependent CPUE time series of observed recreational angler catch rates (**?**).

This paper focuses on the development of methods to select samples from a larger survey that represent the appropriate effort directed at a species of interest. We developed standardized indices of abundance based on different data filtering methods for a fishery-dependent survey of the recreational fishing fleet.

2. Methods

2.1. Survey Data

The California Department of Fish and Wildlife (CDFW) has conducted a fishery-dependent onboard observer survey of the Commercial Passenger Fishing Vessel (CPFV or party/charter boat) fleet since 1999. Since 2004, the survey became part of the California Recreational Fisheries Survey (CFRS). Sampling effort for groundfish-targeted CPFV trips was distributed in proportion to fishing effort. In California, approximately xx% of the recreational CPFV effort is north of Point Conception. Vessels are required to carry observers if requested, but observers may not be allowed on a vessel if the vessel is at full capacity. This is more common in northern California where a number of charter boats are smaller 6-pack vessels with limited capacity.

Groundfish-targeted CPFV trips were sampled opportunistically as CPFV participation is voluntary and sampling effort was distributed in proportion to fishing effort. In California, xx% of the recreational CPFV effort is north of Point Conception. Observers may not be allowed on a vessel if the vessel is at full capacity, which is more common in northern California where a number of charter boats are smaller 6-pack vessels with limited capacity.

On a trip, observers recorded information for each fishing drop, each time lines were in the water. Just prior to the start of each fishing drop, the sampler selected a subset of anglers to observe, at maximum of 15 anglers per fishing drop. The sampler recorded all fish encountered (retained and discarded) by the subset of anglers as a group. Samplers also recorded the time fished (starting when the captain announced

“Lines down” to when the captain instructed anglers to reel lines up), GPS coordinates of the fishing drop (start and/or end latitude/longitude), and minimum and maximum bottom depth. Fish encountered by the group of observed anglers were recorded to the species level as either retained or discarded, providing a count of each species at a particular location. Discarded fish were measured for length and some portion of retained fish were measured as part of a different CRFS Sampling program. The catch and fishing time of an individual angler were not recorded. Additional details can be found in Monk et al. (**?**).

In 2001, the California Polytechnic State University Institute of Marine Science, San Luis Obispo (Cal Poly) began conducting a supplemental onboard observer program of the CPFV fleet based in Port Avila and Port San Luis along the Central Coast. Protocols for the Cal Poly survey were the same as the CDFW survey, with the exception that Cal Poly measured retained and discarded fish from observed anglers.

A common phenomenon of ecological data is the high proportion of zero observations across samples and the question as to whether the sampling occurred within the species' habitat and the species was not observed or if the sampling occurred outside of the species' habitat (structural zeroes).
Fisheries survey data are often subset to exclude structural zeroes using the Stephens-MacCall method, which looks at the species composition of co-occurring species. However, the onboard observer survey collected location-specific information on each observer fish encounter. To subset the onboard observer survey data and exclude structural zeroes, we used the positive catch locations as a proxy for suitable habitat.

2.1.1. Species

We explored the methods described in the following sections to develop indices of abundance for fourteen species or species complexes of management interest: black rockfish (*Sebastes melanops*), blue and deacon rockfish complex (*Sebastes mystinus*, *Sebastes diaconus*), brown rockfish (*Sebastes auriculatus*), China rockfish (*Sebastes nebulosus*), gopher rockfish (*Sebastes carnatus*), rosy rockfish (*Sebastes rosaceus*), and vermilion and sunset rockfish complex (*Sebastes miniatus*/*Sebastes crocotulus*). Species complexes consist of two cryptic species that may or may not be genetically distinct, but cannot be assessed separately for various reasons including the inability to separate catch histories between species or difficulty of visual species identification. Gopher rockfish was assessed as part of a species complex with black-and-yellow rockfish (*Sebastes chrysomelus*) in 2019, but are visually identifiable (**?**).

Versions of the area-weighted habitat index of relative abundance were approved by the Pacific Fisheries Management Council's SSC for use in stock assessments in 2013 have been used in xxx assessments accepted for management (China, gopher/black-and-yellow, vermilion/sunset, blue/deacon, black, lingcod - cite assessments).

2.1.2. Treatment of Data

The onboard observer data provide a high-resolution of catch, effort and the ability to map the fishing drops to fine-scale habitat data. This paper explores methodological differences in data treatment to see what we gain by having the high-resolution habitat data and using that as a mechanism to filter out trips that are not targeting the species of interest. To do this, we first aggregated the drop-level species encounter data to the trip-level to mimic the collection of dockside data. Effort (angler hours) was calculated for each drop and summed across a trip to estimate total effort for the trip. Trip-level data were then filtered using the Stephens-MacCall approach and three different data selection methods were applied using the Stephens-MacCall results (see description below). In the resulting indices of abundance, the only spatial covariate explored was the county of landing.

The second filtering approach used the high resolution drop-level data, but assumed no available habitat data. The percent of groundfish encountered during a drop was assumed as a proxy for habitat. The third approached used the fishing drop-level data, incorporated habitat as a filter for data selection, and applied area weights to the index, using the total area of rocky habitat as the weights. In addition, all of these approaches were applied with and with out the supplemental data from the Cal Poly observer program to illustrate the effect of additional data on indices for species with population ranges centered in central California.

The onboard observer data provide a suite of data including catch, effort, bottom depth, and the latitude/longitude of each fishing drop. This paper explores methodological differences in data treatment to determine changes in trends in indices and the associated error among three alternative assumptions and data filtering strategies. All of the methods described below started with the same subset of drifts from the onboard observer data, restricted to state waters and the years 2001-2016. In the case of application to stock assessments, all potential data are explored, which may be why trends in indices differ in this paper than what has previously been published in stock assessments. Since the most recent stock assessments in 2021, the data have undergone a major quality assurance effort by the authors.

The majority of available recreational fishing data are collected by sampling anglers and vessels dockside, after the completion of a fishing trip.We mimicked the collection of dockside data by aggregating all of the fish encountered within a single trip and summing the effort among drifts. In this case, each trip is a sampling unit. Trip level data were then filtered using the Stephens-MacCall approach (see description below), and only county was used as a spatial covariate in the indices. This approach was applied with and without the supplemental data collections by Cal Poly.

The second approach used the high resolution drift data, but assumed no available habitat data and applied the Stephens-MacCall filtering approach, again with and without the supplemental sampling data from Cal Poly.

The third approached used the fishing drop level data, incorporated habitat as a filter for data selection, and compares indices with and without area-weighting using the area of hard substrate within a region as a proxy for habitat.

All indices of abundance were coded in R and the Bayesian analyses were conducted using the rstanarm package.

Analyses were limited to the California coast north of Point Conception ($34°27'N$). The composition of the fish communities in southern California differ, and the recreational fisheries are fundamentally different, with a higher percentage of trips targeting mixed species and pelagic and highly migratory species, as well as more limited access to rocky habitat nearshore. Point Conception is a biogeographic break (citation) and a number of stock assessments In addition, complete habitat data are not available for areas in southern California. The data were also temporally restricted to the years 2001-2016. Earlier and more recent data were excluded to preserve a dataset with the most consistent gear and depth regulations.

2.1.2.1. Stephens-MacCall Data Selection Filtering. The trip-level index uses all available data before any filtering was done to exclude individual drifts with missing effort or location data. The trip-level effort was calculated as angler days, using the average number of observed anglers across all drifts on a trip. This imitates the method for which effort is calculated for the observed catch from CRFS angler interviews.

The Stephens-MacCall (**?**) filtering approach was used to predict the probability of encountering the target species, based on the species composition of the catch in a given trip. The method uses presence/absence data within a logistic regression to identify the probability of encountering a target species given the presence or absence of other predictor species. This method is commonly used to filter data that are collected dockside after a vessel returns to port. Prior to applying the Stephens-MacCall filter, we identified potentially informative predictor species, i.e., species with sufficient sample sizes and temporal coverage (present in at least 5% of all trips) to inform the binomial model. The remaining species all co-occurred with the target species in at least one trip and were retained for the Stephens-MacCall logistic regression. Coefficients from the Stephens-MacCall analysis (a binomial GLM) are positive for species that are more likely to co-occur with the target species, and negative for species that are less likely to be caught with target species.

While the filter is useful in identifying co-occurring or non-occurring species assuming all effort was exerted in pursuit of a single target, the targeting of more than one species or species complex ("mixed trips") can result in co-occurrence of species in the catch that do not truly co-occur in terms of habitat associations informative for an index of abundance. Stephens and MacCall (**?**) recommended including all trips above a threshold where the false negatives and false positives are equally balanced. However, this does not have any biological relevance and for this particular data set where trained observers identify all fish. We assume that if the target species was encountered, the vessel fished in appropriate habitat.

Stephens and MacCall (**?**) proposed filtering (excluding) trips from the index standardization based on a criterion of balancing the number of false positives and false negatives. False positives (FP) are trips that are predicted to encounter the target species based on the species composition of the catch, but did not. False negatives (FN) are trips that were not predicted to encounter the target species, given the catch composition, but caught at least one. The trips selected using this criteria were compared to an alternative method including all the "false positive" trips, regardless of the probability of encountering the target species. The catch included in this index and in the angler interviews collected by CDFW is sampler-examined and the samplers are well trained in species identification. Therefore, we make the assumption that species were positively and correctly identified. Three data selection methods were applied to the Stephens-MacCall method, the data selection method proposed in the original manuscript to balance the false negatives and the false positives, retention of all positive encounters and exclude of only false negatives, and the method described in (xxxx).

Started with 2,252 trips that retained at least one fish.

A Stephens-MacCall filter was also applied to the data with each individual drift as a sample. The used a cutoff of 1% of all drifts for the drift-level Stephens-MacCall analysis, minimum drifts of 186

2.1.2.2. Data Selection Including Habitat. Drift level data selection was Total drifts is 19,425 and after removing drifts with missing effort information left with 19,180

Upper and lower 1% of the data removed for fish time and observed anglers, leaving drift times between 3 and 96 minutes and observed anglers between three and 15 anglers, and <= 4 leaving 18,591 drifts.

For indices incorporating habitat information, we filtered the depths to ensure that appropriate information was used. We did not use depth within the indices as a predictor. The fishery was closed deeper than 40 fathoms for the entire time period, and the additional 6 fathoms is within the scope of error depending on the bottom habitat.To remove drifts that may not have targeted groundfish, we removed drifts deeper than the 99% quantile, 46.6 fathoms, retaining 18,405 drifts.

The distance from rocky habitat composed the last filter for the habitat and area-weighted indices. We retained 90% of the drifts with the target species from the cumulative frequency table of distance to rocky habitat. The cutoff for blue, China and gopher rockfish was six meters, eight meters for vermilion rockfish, 14 meters for black rockfish and 16 meters for brown rockfish.

ReefDistance cutoffs used Black 14 m Blue 6 m Brown 16 m China 6 m Gopher 6 m Vermilion 8 m

2.1.2.3. Indices of Abundance. Standardized indices of abundance were generated for each data filtering method.

All indices were modeled using a Bayesian genearlized linear models (GLMs). The onboard observer data were analyzed using the delta method with two generalized linear models (delta-GLM). The first GLM models the probability of encountering the species of interest with a binomial likelihood and a logit link function. The second GLM models the positive encounters with either gamma or lognormal errors structure.

We explored the possibility of area-weighted indices, using the area of the reefs as the weighting scheme.

Indices of abundance modeled the catch per unit effort (angler hours) and possible covariates trip-level data were 3-month wave and county of landing. Covariates considerd for the drop-level data included, aggregated reef area, 3-month wave, dep and

Standardized indices of abundance were generated for each data filtering method using generalized linear models and methods approved for use in West Coast groundfish stock assessments. All indices were modeled using Bayesian generalized linear models (GLMs); species with high positive encounter rates were modeled with a negative biniomial and species with lower encounter rates were modeled using a delta method (**?**). The delta method models the data with two separate GLMs; one for the probability of encountering the species of interest from a binomial likelihood and a logit link function and the second GLM models the positive encounters with either gamma or lognormal error structure. The gamma or lognomal model was chosen by AIC from the full model.

Indices of abundance modeled the catch per unit effort (angler hours) and possible covariates.

Year was always included in the mo trip-level data were 3-month wave and county of landing. Covariates considerd for the drop-level data included, aggregated reef area, 3-month wave, depth, and xxxx. We explored the possibility of area-weighted indices, using the area of the reefs as the weighting scheme.

All indices of abundance were coded in R and the Bayesian analyses were conducted using the rstanarm package.

2.1.2.4. Habitat Data. We identified rocky habitat and defined reefs as potential habitat for rockfish in California from multiple bathymetic data sources. Bathymetry within California state waters north of Point Conception ($34°27'N$) was mapped at a resolution of 2 m by the California Seafloor Mapping Program (CSMP).Rough and smooth substrate was identified by CSMP using 2 rugosity indices based upon bathymetric data, surface:planar area, and vector ruggedness measure (VRM). We considered areas identified as 'rough' as reef habitat. While there were fishing drops outside of state waters, we limited data for the comparisons presented in this paper to state waters with known habitat.

Individual reefs at the finest scale were defined as raster cells of rough habitat greater than 200 m apart. The distance was chosen based on evidence that a number of nearshore rockfish exhibit site fidelity and a number of tagging studies have recaptured close to original capture sites (**????**). If raster cells representing hard substrate were contiguous (not separated by soft habitat by greater than 200 m) it remained intact, no matter how large the reef. Reefs were further defined with a 5 m buffer to account for potential error in positional accuracy.

Individual drifts were assigned to reefs based on the recorded start location, given that the end locations were not always available. Reefs within predetermined larger regions were designated to gain appropriate sample sizes needed for modelling and the areas of the hard habitat were summed.

3. Results

4. Discussion

Recent studies have identified the need to investigate the assumptions and uncertainty in relative indices of abundance from visual surveys (Bacheler and Shertzer 2015, Campbell et al. 2015, Schobernd et al. 2013) and simulation studies (Siegfried et al. 2016).

Magnusson and Hilborn 2007 - prioritize data for stock assessments

Stock synthesis weighting of indices based on CVs - is the CV tighter for the fishery-independent survey to give it have an edge over the onboard observer survey?

CDFW sampler manual - "10 anglers should be the target number of observed anglers"

encompass the entire range of the species. However, the point of the exercise is to compare the two methods and these surveys are sampling the same habitats in the SCB

Survey indices can be either absolute or relative. In the case of an absolute index of abundance, the entire population within the sampling area is accounted for and the index also provides information on the density of the fish species within that area as well as aid in scaling the population size within the stock assessment model. Most indices of abundance are relative due to the fact that the entire population within the survey area was not observed. Estimates of absolute abundance are difficult to obtain, especially for cryptic rockfishes. The cowcod (*Sebastes levis*) stock assessments is one of the only West Coast stock assessments that has incorporated an estimate of absolute abundance, derived from a visual survey [**?** et al. 2005). The majority of stock assessments include one or more index of relative abundance.

Composition data from recreational surveys had the largest impact on simulation results, but individual survey components did not have individual effects on benchmarks (Siegfried et al. 2016).
The onboard observer surveys decrease the amount of uncertainty, but relative to a fishery-independent survey, is still high. . . .

A key assumption of the onboard observer programs is that fishing behavior remains the same when observers are not onboard the vessel. If a captain only fishes particulat locations or targets a different suite of specides when an observer is onboard the vessel, additional bias is introduced in the data

5. Tables

6. Figures

References