Comparison of indices of relative abundance from recreational fishery-dependent surveys

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Abstract

This is the abstract.

It consists of two paragraphs.

Introduction

Fisheries stock assessments rely on a wide range of data to model a population to fully understand the dynamics. 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. The West Coast groundfish Fishery Management Plan (FMP) includes 64 rockfish species, _____ of which do not have full stock assessments. Fisheries survey and catch data are used to develop standardized indices of abundance that inform fisheries stock assessment models (Maunder and Punt, 2004). Catch per unit effort (CPUE) is a common metric collected from fishery-dependent or fishery-independent surveys, with the latter providing unbiased data. However, fishery-independent surveys can be costly, labor intensive and often require a long time series to be considered informative in fisheries stock assessments. Advantages of fishery-dependent data is that it is collected directly from the the fishery whose operations are not constrained by sampling designs, but dependent on the behaviors of the captain and, in the case of recreational trips, customer preference. Fishery-dependent 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 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.

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Depending on the stock assessment model and the available data for the fish stock, the index can have large influence on the assessment results (find examples).

There are only two long-term fishery-independent surveys that span the U.S. West Coast that survey groundfish populations and neither are informative for nearshore rockfish species. The National Marine Fisheries Service Southwest Fisheries Science center conducts a juvenile rockfish and ecosystem survey using a midwater trawl and the West Coast Bottomfish Trawl (WCGBT) survey utilizes a xxx trawl to sample groundfish populations deeper than 55 m. However, many of the important rockfish species inhabit untrawlable habitat and in depths shallower than the 55 m sampled by the WCGBT survey. The California Collaborative Fisheries Research Program (CCFRP), a fishery-independent hook-and-line survey, was designed to monitor California's network of Marine Protected Areas. The CCFRP was limited to the central coast of California from 2007-2016, and expanded to cover the entire California coast in 2017. Indices of abundance developed from this program have informed nearshore rockfish stock assessments in recent years (**Monk2019?**; **Monk2021?**). The CCFRP is not without its limitations in terms of spatial coverage and

An index of relative abundance assumes that changes in the index are proportional to changes of abundance in the population, which does not always hold or may not be linear (**Harley2001?**).

Along the U.S. West Coast, even if the stock assessment is categorized as data rich, oftentimes the the only index of abundance available is from a fishery-dependent CPUE time series of observed recreational angler catch rates (Cope, 2013).

There is currently no coastwide fishery-independent survey for the nearshore fisheries on the West Coast. The National Marine Fisheries Service (NMFS) conducts an annual trawl survey, but the survey extends to a minimum depth of _____ (cite) and is known not to select for all rockfish species due to the inability to trawl in rocky habitats. Several scientists are developing methods to survey untrawlable habitat and small areas of fishery-independent survey work are available. Propose survey methods include the use of stereo video landers (cite), acoustic surveys (cite), remotely operated vehicles (ROVs), as well as hook and line surveys. There are three ongoing hook and line surveys on the West Coast, two of which were designed to monitor MPA networks in central California (CCFRP) and Oregon (ODFW Marine Reserves Program). T

In California, approximately 70% of the recreational fishing effort is in the SCB, and since the survey effort distributed proportional to effort, there are a large number of fishery-dependent data available for the SCB that overlap with the NWFSC hook and line survey fixed stations.

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

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 scientific fishery-independent survey.

Fishing effort directed toward a specific species or species complex

This paper focuses on methods to determine the appropriate trips to represent effort and the resulting indices of relative abundance from a fishery-dependent survey of the recreational fishing fleet. We apply multiple methods to learn how abundance indices change with available information, as well as look at the inclusion of supplement data collected by Cal Poly. Cal Poly began an onboard observer program following the same methods as CDFW in 2001.

Groundfish Management. There are a number of management changes that have affected West Coast groundfish species over the last few decades. In 2000, West Coast groundfish fisheries were declared a disaster (citation) as a number of stocks were declared overfished with overfishing occurring. In response to federal management measures, the CDFW implemented fishing gear regulations of 3-hooks per line and one-line maximum per angler in 2000, and that changed to a 2-hook per line and one-line maximum in 2001. CDFW also bagan temporal and spatial management in the forms of closures and depth restrictions in 2004. Boundaries of the regional management units have changed over time and are accounted for in our analyses. In 2007, California enacted a network of Marine Protected Areas that encompass approximately 23% of state waters. As groundfish stock have rebuilt over the last few years, CDFW eased depth restrictions in some management areas and the recreational groundfish fleet had access to depths outsdie of state waters.

Methods

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). 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. (**Monk2014?**).

In 2001, the California Polytechnic State University Institute of Marine Science, San Luis Obispo (Cal Poly) conducts a similar 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 are the same as the CDFW survey, with the exception that Cal Poly measures 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.

Species. We explored the methods described in the following sections 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*), copper rockfish (*Sebastes caurinus*), gopher and black-and-yellow rockfish complex (*Sebastes carnatus*, *Sebastes chrysomelas*), greenspotted rockfish (*Sebastes chlorostictus*), olive rockfish (*Sebastes serranoides*), quillback rockfish (*Sebastes maliger*), rosy rockfish (*Sebastes rosaceus*), starry rockfish (*Sebastes constellatus*), vermilion and sunset rockfish complex (*Sebastes miniatus*/*Sebastes crocotulus*), yellowtail rockfish (*Sebastes flavidus*). 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. 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).

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 data. To do this, we first mimic the collection of dockside data by aggregating all of the fish encountered within a single trip and summing the effort among drifts. 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), and only county was used as a spatial covariate in the indices.

The second approach used the high resolution trip data, but assumed no available habitat data. The percent of groundfish encountered during a drift 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 an area-weighted index using the area of the reef within a region as a proxy for habitat.

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 a distirbution centered in central California.

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 gera and depth regulations.

Stephens-MacCall Filering The Stephens-MacCall (2004) filtering approach was used to predict the probability of encountering a target species, based on the species composition of the catch in a given trip. The method uses presence/absence data wthin a logistic regression to identify the proability of encountering a target species given the presence or abance 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 (2004) 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 data set, and we assume that if the target species was encountered, the vessel fished in appropriate habitat.

Stephens and MacCall (2004) 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 dockside data 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).

Indices of Abundance. Standardized indices of abundance were generated for each data filtering method. 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, depth, and xxxx.

All indices were modeled using a Bayesian genearlized linear models (GLMs). Species with high positive encounter rates were modeled with a negative biniomals

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.

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 exchit site fidelit and a number of tagging studies have recaptured close to original capture sites (Hannah et al., 2012; Hannah and Rankin, 2011; Lea et al., 1999; **Matthew1990?**). 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.

Fishing drops 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.

Results

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).

Linear relationship between density from SCUBA surveys and a fishery-independent survey for rockfish when in the species preferred habitat and gear (Haggarty and King 2006) and for the more abundance species (Richards and Schnute 1986).

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?

Starr et al. (2010) compared SCUBA methods to commercial fishing gear, but only sampled for two year.

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 [(**Piner?**) 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. . . .

Assume fishing behavior is remains the same when observers are no onboard the vessel.

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