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Collecting age and length data from recovered carcasses of filleted rockfish: a new data source for examination of life history characteristics

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Abstract—In reports on stock assessments for rockfish species on the West Coast of the United States, the need for additional biological data to provide more accurate estimates of population abundance is commonly cited. Improvement of population estimates is important because those data are used to set catch quotas along this coast of the nation. The recreational charter boat fleet in the state of California has historically landed large amounts of rockfish species; however, vessels in this fleet discard carcasses once fillets have been removed from fish. These carcasses could be a valuable source of age, length, and sex data, with a standardized measurement method used to relate the post-fillet length of carcasses to the pre-fillet length. To determine the feasibility of a program to collect rockfish carcasses for biological data, specimens of 4 rockfish species were captured off the central coast of California and measured before and after filleting. Pre-fillet lengths were accurately predicted on the basis of post-fillet elongate length for blue (*Sebastes mystinus*), gopher (*S. carnatus*), copper (*S. caurinus*), and vermilion (*S. miniatus*) rockfish. A high percentage (87.5%) of the carcasses had identifiable gonads, a fortunate result because the availability of sex data on measured specimens is an important consideration for species with dimorphic growth. This new data source based on information from carcasses can be used to enhance the length-at-age and life history data available for stock assessments or other biological studies of rockfish populations.

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The rockfish complex along the central coast of California is composed of 45 managed species that have a wide array of life histories and of preferred habitat and depth ranges. Rockfish species are generally long-lived and slow growing; therefore, effective management is crucial to maintenance of sustainable population levels (Love et al., 1990). An increased level of data on the West Coast rockfish stocks could enhance stock assessments and estimates of population abundance, which are used to set catch limits for rockfishes along the U.S. West Coast, including along the coasts of California, Oregon, and Washington. Stock assessments are important fisheries management tools used to provide resource managers with information needed to monitor and manage fish populations, but large amounts of data are required to run a full age-structured population model as part of an assessment (Hilborn and Walters, 1992; PFMC[1]).

Stock assessment reports for West Coast rockfish populations commonly cite a need for additional biological information, such as length, age, abundance, and sex ratio data, to improve the estimates of population abundance derived through the stock assessment process (e.g., PFMC[2]).

Biological data can often be a limiting factor in the quality of a stock assessment, and a lack of biological data often results in reduced mandated harvest levels because of a precautionary management approach (Ralston et al., 2011). A rockfish stock assessment can fall into 1 of 3 categories: 1) data rich (full), 2) data moderate, or 3) data limited (Ralston et al., 2011). Many rockfish stocks are considered

[1] PFMC (Pacific Fishery Management Council). 2020. Terms of reference for the groundfish and coastal pelagic species stock assessment review process for 2021–2022, 38 p. Pac. Fish. Manag. Counc., Portland, OR. [Available from website.]

[2] PFMC (Pacific Fisheries Management Council). 2019. Gopher/black and yellow rockfish stock assessment review (STAR) panel report; Santa Cruz, 22–26 July, 15 p. Pac. Fish. Manag. Counc., Portland, OR. [Draft report.] [Available from website.]

data limited or data moderate, and the availability of data can vary by state or region. Full stock assessments require the most data and include age-specific estimation of abundance and biomass as well as modeling of fish growth and mortality (PFMC[1]). Data-moderate assessments include length and abundance data that are used to create an estimate of stock status. Data-limited assessments lack an estimation of stock status and are used mainly to inform mandated harvest levels. Rockfish stocks that fall into the data-limited category or data-moderate category are subject to more conservative quota levels because of greater uncertainty in biomass estimates (Ralston et al., 2011).

Four socioeconomically valuable rockfish species with recent stock assessments and research recommendations identifying the need for additional data include the blue rockfish (*Sebastes mystinus*), gopher rockfish (*S. carnatus*), copper rockfish (*S. caurinus*), and vermilion rockfish (*S. miniatus*). The blue rockfish is the target of one of the most important recreational fisheries in California, and it is particularly key for the recreational charter boat fleet (a vessel in this fleet is hereafter referred to as a *party boat*), which accounted for 50% of total landings of blue rockfish off the coast of California over the past decade (Dick et al., 2018). The blue rockfish forms a species pair with the deacon rockfish (*S. diaconus*); these species are visually distinct but easily misidentified when morphology alone is used. Although work has helped to make it possible to more readily distinguish these species (Frable et al. 2015), the blue rockfish is particularly data limited prior to 2015 because all historic and some recent data are a mix of information on blue and deacon rockfish in unknown proportions (Dick et al., 2018). In the report on the latest stock assessment for the blue and deacon rockfish complex, it was noted that the estimate of the size of the blue rockfish population is imprecise, partly because of the lack of age data (Dick et al., 2018).

The gopher rockfish is another economically important species that is commonly encountered by the party boat fleet, particularly north of Point Conception in Southern California (Monk and He[3]). In 2011, Port San Luis, on the central coast of California, had the highest landings of gopher rockfish in California, a peak in a trend that has been elevated since 1990, with over 136,000 kg (over 300,000 lb) of gopher rockfish landed by the commercial fishery (Lisa Wise Consulting Inc.[4]). In the report on the most recent stock assessment for the complex that includes the gopher rockfish and the black-and-yellow rockfish (*S. chrysomelas*), a need for more age and length data was discussed (Monk and He[3]). This need exists in part because of historic misidentification between gopher and black-and-yellow rockfish; indeed, these species could not be differentiated in catch data before 1995 (Monk and He[3]).

Copper rockfish also have been an important part of both recreational and commercial fisheries; however, this species is considered data moderate, because of the lack of length, age, and length- or age-at-maturity data that could be used to determine stock status (Cope et al., 2015; Wetzel et al., 2021). Prior to 2013, no stock assessments had been conducted for copper rockfish, although this species is considered to be the most vulnerable rockfish species found off the West Coast (Cope et al., 2015). Therefore, accurate catch and biological data are especially vital for this species.

The vermilion rockfish is another species that has been historically important in the recreational fishery, given its desirability as a brightly colored, large species (Monk et al., 2021). Yet, the most recent stock assessment report cites a need for more biological data, including better indices of abundance, and biological sampling (Monk et al., 2021). This need is due in part to the morphological similarities between vermilion and sunset rockfish (*S. crocotulus*). These similarities have resulted in all historical and recent recreational and commercial catches of sunset and vermilion rockfish being recorded as catches of vermilion rockfish, limiting the available data (Monk et al., 2021). Because of differences in size composition and population structure between vermilion rockfish found in Northern and Southern California, separate stock assessments are provided for each of these regions. Although Northern California represents a larger portion of the coastline of California, very little biological data is available for this species in this region (Monk et al., 2021).

For all 4 species—the blue rockfish, gopher rockfish, copper rockfish, and vermilion rockfish—there is a lack of biological data throughout their ranges, and for all except the copper rockfish, this lack of data is in part due to morphological similarities with other species. Filling these data gaps is a critical need for the management of these socioeconomically valuable species.

One underutilized source of biological data are carcasses of rockfish that have been retained aboard party boats after captured fish have been filleted. The party boat fleet emerged in 1920 in California and has since become one of the largest recreational fleets in the world, with rockfish species among the most desirable targets (Young, 1969; Hill and Schneider[5]). Generally, the fillets collected aboard a party boat are taken home by the angler, and the carcasses are discarded at sea. These carcasses could be a valuable source of length, age, and sex data for the catch of the party boat sector of the recreational fleet. Many rockfish species have sex-specific growth patterns; therefore, for the length-at-age and sex information from carcasses of filleted rockfish to be useful, accurate estimates of prefillet length and sex must be obtainable from the carcasses

[3] Monk, M. H., and X. He. 2019. The combined status of gopher (*Sebastes carnatus*) and black-and-yellow rockfishes (*Sebastes chrysomelas*) in U.S. waters off California in 2019, 175 p. Agenda item H.5, attach. 11. Pac. Fish. Manag. Counc., Portland, OR. [Available from website.]

[4] Lisa Wise Consulting Inc. 2018. Port San Luis commercial fishing industry: economic impact report, 26 p. Lisa Wise Consult., San Luis Obispo, CA. [Available from website.]

[5] Hill, K. T., and N. Schneider. 1999. Historical logbook databases from California's commercial passenger fishing vessel (partyboat) fishery, 1936–1997. Scripps Inst. Oceanogr., SIO Ref. Ser. 99-19, 58 p. [Available from website.]

of filleted fish (Love et al., 2002). The issue is that fish carcass length, with fillets removed, is different from whole fish length, and no information is available currently about how the length of a carcass of a filleted rockfish relates to the pre-filleted length. Information on this relationship is needed before accurate length-at-age data can be obtained from carcasses of filleted rockfish, particularly because carcass lengths likely would be combined with pre-fillet lengths from other data sources (e.g., commercial fleets) in a stock assessment and because standardization of length types is critical.

The idea of back-calculation, using a set of measurements on a fish to infer the total length at another time, is not new to fisheries science (Francis, 1990). In a few studies, back-calculations of total length and length at age have been done by using fish bones (Wise et al., 1980; Hansel et al., 1988), spine radii (Landa et al., 2015), headless fish carcasses (Gordon, 1994), and carcasses of filleted fish (Barnes et al., 2015; Barnes and Starr, 2018). There are currently no studies focused on the relationship between carcass length of filleted fish and total length of pre-filleted fish for the West Coast rockfish stocks. Investigating this relationship, as well as obtaining age data from otoliths, may help in the development of tools that can be applied on a statewide scale to help resource managers understand the state of the recreational fisheries that target rockfish species on the West Coast.

In order to address the unknowns regarding the potential of collecting data for stock assessments from rockfish carcasses sourced from party boats, we focused this study on 3 questions: 1) can a protocol be developed to standardize the measurement of carcasses of filleted fish, 2) what percentage of carcasses have identifiable gonads, and 3) can this method be used to develop a linear regression equation for accurate estimation of pre-fillet length from carcasses of filleted fish? The information from this study can be used by fishery managers to establish a carcass collection program aimed at enhancing the amount of length-at-age and life history data available for stock assessments or other studies of rockfish populations.

Materials and methods

Data for this study were collected primarily by onboard observers of the party boat fleet operating in waters off the central coast of California. The observers were part of a program administered by the California Polytechnic State University in collaboration with the party boat fleet in San Luis Obispo County, California, to gather rockfish fishery data (Stephens et al., 2006). Program observers on regularly operating party boat trips record the location, time, length, and fate of individuals of different fish species that are caught by recreational anglers. These observers follow the same method used for the onboard observer sampling of the California Recreational Fisheries Survey of the California Department of Fish and Wildlife. The primary difference is that, in the university program protocol, retained and discarded fish are measured, and in the California Department of Fish and Wildlife onboard protocol, only retained, not discarded, fish are measured. The data from the university program have been used in the development of indices of abundance and length composition data sets for a number of nearshore rockfish species (e.g., Dick et al., 2018; Monk and He[3]).

In addition to sourcing fish through the Observer Program of the California Polytechnic State University, we conducted several research trips from ports in California, with collections occurring from Half Moon Bay to the Channel Islands. The majority of specimens used in this study were collected from San Luis Obispo County. This county has 2 main ports that support commercial and recreational fisheries: a southern port, Port San Luis, and a northern port, Morro Bay (Fig. 1). Rockfish were collected

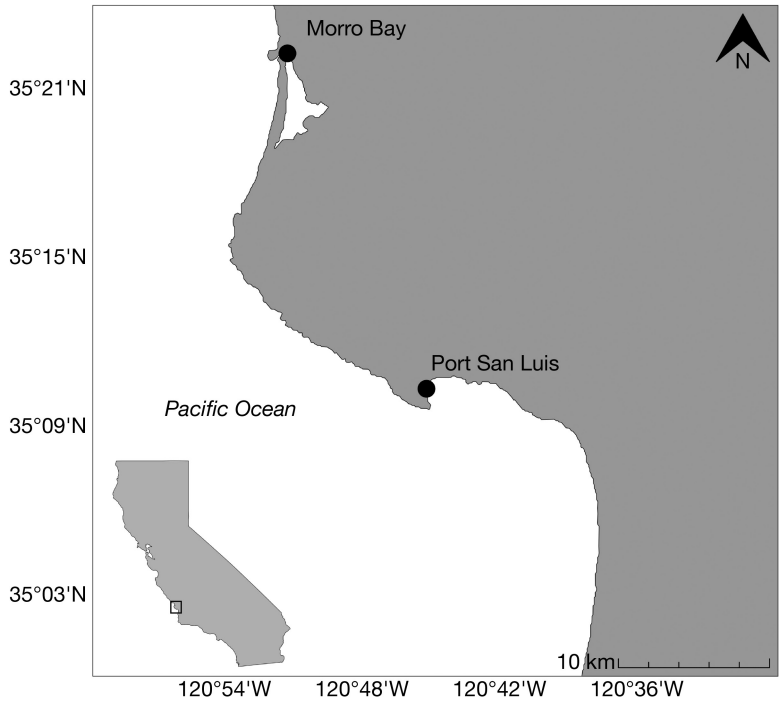

Figure 1

Map of the study region in San Luis Obispo County, California, showing the 2 harbors from which the charter boat trips involved in this study originated: Morro Bay and Port San Luis. The majority of the carcasses of filleted blue (*Sebastes mystinus*), gopher (*S. carnatus*), copper (*S. caurinus*), and vermilion (*S. miniatus*) rockfish used in this study were collected by observers aboard party boats during December 2017–February 2022.

from December 2017 through February 2022. These specimens were caught by using hook-and-line fishing methods with a variety of tackle. Processing of fish was done either onboard the fishing vessel by the boat crew or in a laboratory facility at the California Polytechnic State University by scientific staff within 2 d of being caught. Fish processing included species identification, measuring fork length to the nearest millimeter (from the tip of the snout to the end of the splayed caudal fin on a measuring board), filleting, otolith extraction, sex determination, and measuring post-fillet carcass length by using the procedures described in the next section. The adjustments between pre-fillet and post-fillet lengths developed in this study are intended to be applicable to rockfish that fall within the size distributions used in this study (Table 1). If the models developed in this study are to be applied with a data set for fish with a larger or different size distribution, the models must be adjusted to reflect the correct size distribution.

The most robust measurement technique was determined early on in this study by using a preliminary data set containing fish lengths collected by using different possible techniques to measure a carcass of a filleted fish. A standardized protocol was needed so that it would be possible to develop a reliable length regression equation based on a consistent relationship between post-fillet and pre-fillet lengths. We developed measurement protocols using 29 blue rockfish, individuals of one of the most common species in the study area, to test 3 possible post-fillet measurements: short, natural, and elongate (Fig. 2). All of these measurements were taken on a measuring board like the measurement for standard fork length. The post-fillet short length was taken from the tip of the snout to the end of the splayed caudal fin, with the head of the fish pointed down, the spine of the fish flexed as much as naturally possible, and the carcass kept flat on the board. The post-fillet natural length was taken from the tip of the snout to the end of the splayed caudal fin, with the fish laid on the board in a way believed to be the natural position of a fish with intact fillets. The post-fillet elongate length was taken from the tip of the snout to the end of the splayed caudal fin, with the spine of the carcass hyperextended to the point where the carcass could not be reasonably extended farther. Linear regression was used to describe the relationship between each of the post-fillet measurements and the pre-fillet length.

A sub-study was conducted to determine if there were differences in the relationship of post-fillet length to pre-fillet length due to the varied levels of experience of the scientists from whom length measurements were obtained. Once the measurement methods were developed, it was important to test whether measurements taken with these protocols could be consistent regardless of who took the measurement and their experience. A plot was created to test whether level of experience (novice versus experienced laboratory staff) had an effect on the relationship between post-fillet elongate length and pre-fillet length. This analysis was conducted only for gopher rockfish because there were not enough samples of the other 3 species. Although this test was done for only 1 species, the results are considered representative of what would be expected for all rockfish species included in this study, given their similar body morphologies.

Table 1

The distributions of fork lengths of blue (*Sebastes mystinus*), gopher (*S. carnatus*), copper (*S. caurinus*), and vermilion (*S. miniatus*) rockfish collected through the Observer Program of the California Polytechnic State University and during research trips in waters off the central coast of California from December 2017 through February 2022.

	Fork length (cm)		
Species	Minimum	Maximum	Average
Blue rockfish	14.30	40.70	27.09
Gopher rockfish	18.20	32.90	26.79
Copper rockfish	25.00	47.40	35.65
Vermilion rockfish	15.50	52.00	35.91

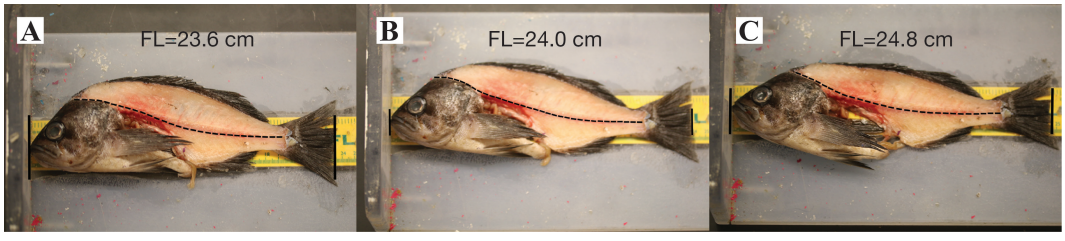

Figure 2

Photographs depicting the differences between 3 methods of measuring the fork length (FL) of carcasses of filleted rockfish: post-fillet (**A**) short, (**B**) natural, and (**C**) elongate measurements. The black dashed line follows the spine of the fish. The filleted blue rockfish (*Sebastes mystinus*) shown in these panels was caught in February 2018 in waters off central California.

We conducted a second sub-study to investigate if sex could be determined from fish filleted by the party boat crew during a regular trip with paying customers; the crew was asked to fillet fish as they normally would. Carcasses of filleted vermilion rockfish were collected on 2 party boat trips out of San Luis Obispo County. After the fish were filleted by crew members, their carcasses were analyzed to determine the fraction of carcasses that had intact and identifiable gonads. Having a high proportion of fish carcasses for which sex could be determined was critical to the efficacy of this study, if the results are to enhance information on sex-specific growth patterns. The identity of the individual processor (vessel crew member who filleted fish) was recorded for a subset of these vermilion rockfish, to test for a potential processor effect on the ratio of intact gonads to missing gonads. This test was important because the variable of processor cannot be controlled in the field. The data from this test were analyzed by using logistic generalized linear regression, with *processor* as the predictor variable and *intact or missing gonad* as the response variable. To determine whether the relationship between length and intact gonad was significant (P<0.05), logistic regression was used, with *length* as the predictor variable and *intact or missing gonad* as the response variable.

Individual regression analyses were conducted by using each of the different measurement methods as the predictor variables and *pre-fillet length* as the response variable for the 4 species noted previously: blue rockfish, copper rockfish, gopher rockfish, and vermilion rockfish. The regression equations obtained for each species were used to calculate pre-fillet length, and the calculated pre-fillet length values were compared to the actual pre-fillet length values. We also tested whether sex was a significant factor in these equations. For each species, outliers identified by using residuals-versus-fitted, normal quantile-quantile (Q-Q), and Cook's distance plots were excluded from analyses. All analyses for this study were conducted by using RStudio (vers. 2021.09.0; RStudio, 2021), the tidyverse collection of R packages (vers. 2.0.0; Wickham et al., 2019), and the R package ggpmisc (vers. 0.5.5; Aphalo et al., 2023).

Results

We found that the post-fillet short length was the weakest predictor of pre-fillet length for blue rockfish (Fig. 3; coefficient of multiple determination [R^2]=0.987, P<0.001, residual standard error [Σ]=0.503). The post-fillet natural length was a strong predictor of the pre-fillet length, but the original pre-fillet length was both over- and underestimated with it (Fig. 3; R^2=0.993, P<0.001, Σ=0.366). Although the natural length was a better predictor of pre-fillet length, there was more room for variability in measurement (Fig. 3). Post-fillet elongate length was also a strong predictor of pre-fillet length and was the most practical method for collecting consistent measurements, as pre-fillet length was consistently overestimated with it and it was the easiest method to implement (Fig. 3; R^2=0.992, P<0.001, Σ=0.390). Once it was determined that post-fillet elongate length was the most practical

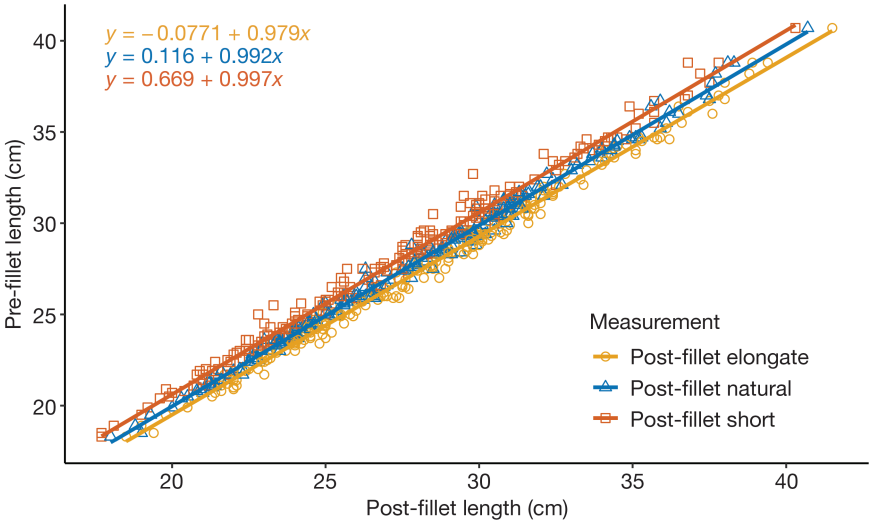

Figure 3

Comparison of the post-fillet elongate (coefficient of multiple determination [R^2]=0.992, P<0.001), post-fillet natural (R^2=0.993, P<0.001), and post-fillet short length measurements (R^2=0.987, P<0.001) to the pre-fillet length for carcasses of filleted blue rockfish (*Sebastes mystinus*) collected from December 2017 through August 2019 during charter boat trips in waters off central California. The linear regression equation is given for each type of measurement.

measurement, only the post-fillet elongate measurement method was used in the rest of the study.

Trained scientific staff and students in a college fisheries course at the California Polytechnic State University measured the pre-fillet and post-fillet elongate lengths of 94 gopher rockfish. The variance in measurements between trained staff and untrained students was not statistically significant (F=1.06, P=0.849); however, the untrained students tended to under-measure the post-fillet elongate length compared to what the trained staff did (Fig. 4).

For the second sub-study, 72 vermilion rockfish were collected and filleted by 2 party boat crew members. The carcasses of 87.5% of these fish had identifiable gonads, and the sex of all carcasses with intact gonads was identifiable. The ratio of intact to missing gonads (18:6, sample size=24) was not substantially different between the 2 crew members filleting fish (note that we were able to track the identity of the crew member who did the filleting for only 24 fish). However, there were not enough samples obtained from the second crew member to statistically compare the data to determine whether the person doing the filleting had a significant effect on whether fish had identifiable gonads. Length was a significant predictor of intact gonads remaining after filleting, with a positive relationship between increasing length and intact gonads (Z=2.767, estimate of the length coefficient=0.245, standard error of the estimate=0.0887, P=0.0057). In comparisons of pre-fillet length, 45.0% of the fish with lengths <40 cm had identifiable gonads and 95.0% of the fish with lengths ≥40 cm had identifiable gonads.

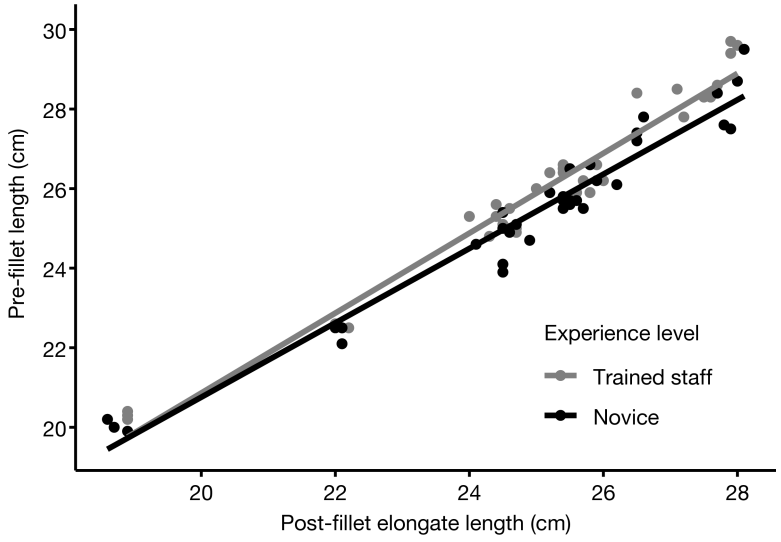

Figure 4

Plot of the pre-fillet lengths and post-fillet elongate lengths of carcasses of gopher rockfish (*Sebastes carnatus*) measured by trained staff and novice students of California Polytechnic State University. Fish were caught and filleted and their carcasses collected during charter boat trips taken between December 2017 and February 2022 in waters off central California.

We developed a linear regression equation for each of the 4 rockfish species, with data collected by measuring the carcasses of filleted rockfish with the post-fillet elongate length measurement method. For each species, a statistically significant relationship was found between post-fillet elongate length and pre-fillet length (Table 2, Fig. 5). Sex was not a significant factor in the linear regression equations.

Discussion

Information about length at age for catches of rockfish species from the party boat fleet on the West Coast is extremely limited, but Schroeder and Love (2002) suggested that the recreational sector can potentially have as large of an effect on fish populations as the commercial sector. The results of our study indicate the feasibility of collecting age and sex information from carcasses to create a new data source of biological information for rockfish species. In San Luis Obispo County, a single party boat can carry between 20 and 50 anglers, depending on the vessel, and the daily bag limit is 10 rockfish per angler per day, with varying species-specific sub-bag limits depending on current management measures. Assuming that 1 vessel carries an average of 30 anglers and each angler catches half of their daily limit, that is 150 carcasses per day per boat. There are approximately 16 party boats in San Luis Obispo County, and the rockfish season is about 270 d (Lisa Wise Consulting Inc.[4]). Therefore, even by a conservative estimate, hundreds of thousands of rockfish carcasses are discarded each rockfish season by the party boat fleet that operates in San Luis Obispo County.

This study is not the first to note the value of obtaining pre-fillet lengths from carcasses of filleted fish. Barnes et al. (2015) used a similar method to create an equation relating the filleted length of California halibut (*Paralichthys californicus*) back to the original pre-fillet length; this equation was used again in a later study (Barnes and Starr, 2018). In both studies, the equation was used to increase the amount of available data because some of the fish from which some of the data were gathered for these studies were from recreational anglers in the form of carcasses of filleted fish (Barnes et al., 2015; Barnes and Starr, 2018). The results of these studies highlight the importance of developing equations to relate the carcass length of filleted fish to their pre-fillet length.

Prior to this study, no research had assessed how the carcass length of a filleted rockfish relates to its pre-fillet fork length. We determined that the carcass of a filleted rockfish can be contorted into 3

Table 2

Results from the linear regression used to estimate the pre-fillet length for carcasses of filleted blue (*Sebastes mystinus*), gopher (*S. carnatus*), copper (*S. caurinus*), and vermilion (*S. miniatus*) rockfish collected and measured during charter boat trips in waters off central California from December 2017 through February 2022. Post-fillet elongate length, measured from the tip of the snout to the end of the splayed caudal fin with the spine of the carcass hyperextended, was used to calculate pre-fillet length. In the regression equations, post-fillet elongate length is used as the predictor value, and pre-fillet length is used as the response value. a=the slope of the line; b=the *y*-intercept; R^2=coefficient of multiple determination.

	Sample size		Linear regression equation				
Species	Males	Females	a	b	R^2	*P*	Residual
Blue rockfish	148	242	0.98	−0.09	0.99	<0.001	0.38
Gopher rockfish	90	105	0.96	0.52	0.97	<0.001	0.49
Copper rockfish	32	40	0.99	−0.55	0.99	<0.001	0.46
Vermilion rockfish	50	78	1.00	−0.44	0.99	<0.001	0.48

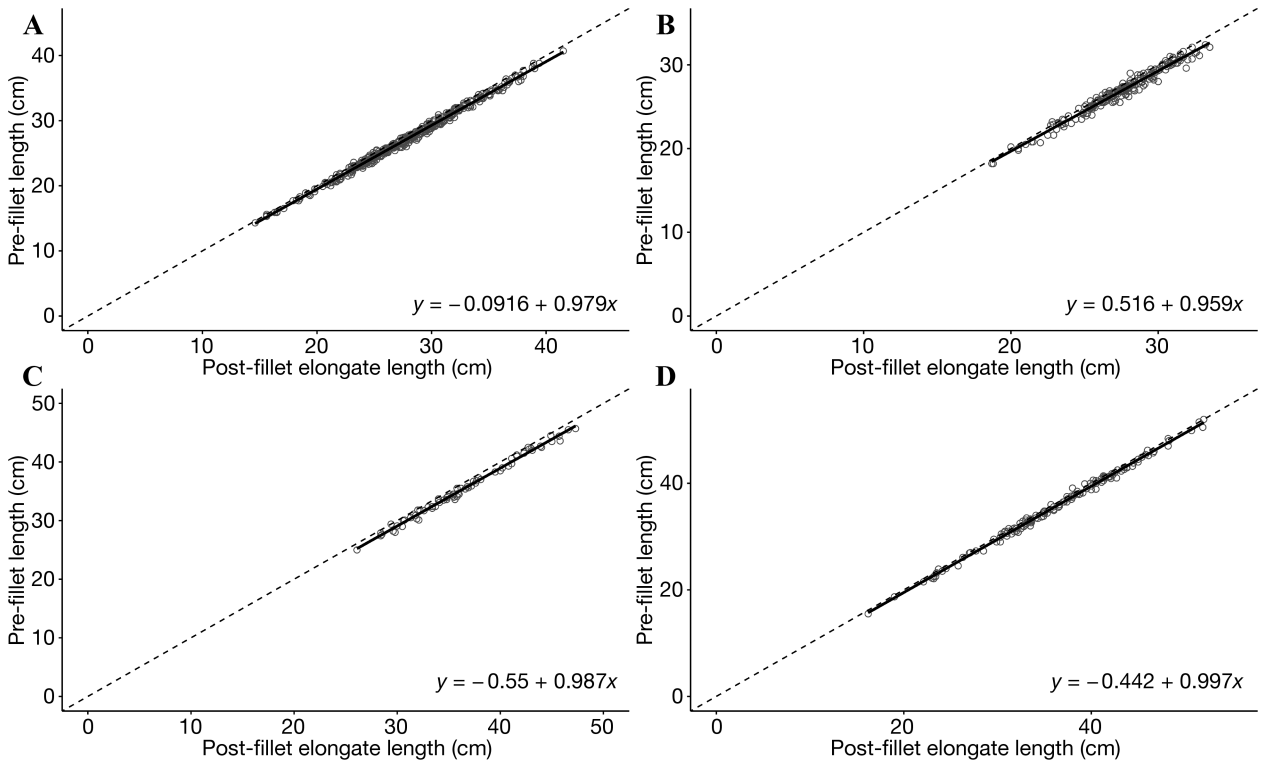

Figure 5

Plots of linear regression depicting the relationship between the post-fillet elongate length and pre-fillet length for carcasses of filleted (**A**) blue rockfish (*Sebastes mystinus*) (coefficient of multiple determination [R^2]=0.99, *P*<0.001, sample size [*n*]=404), (**B**) gopher rockfish (*S. carnatus*) (R^2=0.97, *P*<0.001, *n*=197), (**C**) copper rockfish (*S. caurinus*) (R^2=0.99, *P*<0.001, *n*=72), and (**D**) vermilion rockfish (*S. miniatus*) (R^2=0.99, *P*<0.001, *n*=134) collected during charter boat trips taken from December 2017 through February 2022 in waters off central California. The dashed diagonal line indicates 1:1 equivalence. The linear regression equation is given for each species.

different positions: post-fillet short, post-fillet natural, and post-fillet elongate. We found that post-fillet short length and post-fillet natural length were less precise than post-fillet elongate length and were prone to subjectivity depending on the scientists measuring the fish. When taking the post-fillet short measurement, scientists can arbitrarily shorten the carcass of a filleted fish, by compressing the spine, until they feel it is sufficiently short. Because there is no natural stopping point, the subjectivity in the shortening of a carcass leaves too much room for variability in length measurements. For the post-fillet natural method, determining the "natural" position of the fish was also subjective, and the use of this method led to less consistency in the relationship between pre-fillet length and post-fillet natural length than the use of the other methods. Post-fillet elongate length was determined to be less prone to variability due to measurer judgment because, fish to fish, the backbone could be hyperextended only a small and relatively consistent amount. Use of this method resulted in post-fillet lengths that were consistently longer than the pre-fillet length. Results of the regression analyses indicate strong relationships between all 3 post-fillet measurements and pre-fillet length. However, post-fillet elongate length was the most consistent measurement, providing precise measurements that could be used to calculate accurate estimates of pre-fillet length.

The degree of training did not affect the variance of post-fillet elongate lengths; however, the untrained students tended to under-measure post-fillet elongate length. Understanding this trend is important because, if this method is to be implemented on a statewide level, scientists measuring fish must be able to get similar measurements regardless of their level of training.

Preliminary data from assessment of the presence of identifiable gonads in filleted vermilion rockfish indicate that the majority of carcasses had identifiable gonads remaining. The fish that did not have identifiable gonads were typically smaller than 40 cm in pre-fillet length. These initial data indicate that the relationship between the percentage of carcasses with identifiable gonads and the person filleting the fish was not significant. Consideration of this relationship is important in implementing a carcass collection program, given that fish will likely be filleted by a number of different deckhands. Variability in the percentage of fish with intact gonads among the sets of fish filleted by different crew members could compromise the value of the gonad data if not enough carcasses had intact gonads available to identify the sex of fish. More data on how the individual doing the filleting affects the intactness of gonads are needed for vermilion rockfish and for any other rockfish species before carcass collection programs can be implemented. The collection of samples throughout the period of this study required close collaboration with recreational anglers and the party boat industry. Productive collaboration with industry partners will undergird the success of future programs.

It was determined that pre-fillet lengths could be accurately predicted from precise measurements of post-fillet elongate length for blue, gopher, copper, and vermilion rockfish. These data, combined with age estimates from analysis of otoliths and sex data from carcasses of filleted fish, hold great potential to generate a large amount of biological data that can be used in stock assessments. The methods outlined in this study can be used, for other species of rockfish, to implement a comprehensive program with the party boat fleet in California aimed at enhancing the amount of length-at-age and life history data available for stock assessments or other estimates of rockfish populations. Collaborative networks with available staff are in place and could make it possible for fish with fillet-only measurements to be processed immediately or to be frozen for processing later. Because our technique enables the calculation of the pre-fillet length, otoliths in fish carcasses can become another valuable source of biological data for stock assessments.

Our study results indicate the power of collaborative fisheries programs that involve scientists working directly with industry partners to produce data for fisheries management; of course, this study is not the first with findings that indicate the effectiveness of such programs (Wendt and Starr, 2009; Feeney et al., 2010; Yochum et al., 2011; Mason et al., 2020; Johnston et al., 2024). The Observer Program of the California Polytechnic State University has longstanding relationships with recreational anglers and party boat companies and crews in San Luis Obispo County (Stephens et al., 2006). These relationships were leveraged when developing the methods used in this study, and we found that party boat crews and recreational anglers generally were eager to help and curious about the data being collected. It is expected that the working relationship of the Observer Program with the community of anglers in San Luis Obispo County could provide a framework for other entities looking to establish such collaboration in other places. Cooperative relationships are critical to the success of any study designed to collect information from party boats. Anglers aboard party boats from Alaska to Baja California, Mexico, regularly catch rockfish, and the protocol described herein may allow researchers to add a significant amount of data that can be used in stock assessments and other efforts to estimate the abundance of rockfish populations.

Conclusions

Accurate and precise age, length, and sex data are critical components of stock assessments. Three measurement methods were tested to determine if there was a way to obtain a standardized post-fillet measurement from a carcass of a filleted rockfish. It was found that gonads can be identified, and sex was determined from the majority of carcasses of filleted fish. We also tested whether these data can be used to develop linear regression equations that allow the accurate calculation of pre-fillet length based on the measured post-fillet length of a fish carcass. The results of this study indicate that post-fillet elongate length is an easily incorporated and accurate predictor of pre-fillet length. Together with information from otoliths and gonads

extracted from carcasses of filleted fish, the length information that can be collected through the protocol established in this study could form an extensive set of valuable length-frequency and life history data for historically data-poor or data-limited rockfish populations. The information from this study can be used by staff of government agencies, such as NOAA or the California Department of Fish and Wildlife, to determine the feasibility of establishing a program for collecting carcasses from the party boat fleet in California to enhance the amount of length-at-age and life history data available for stock assessments or other efforts to estimate abundance of rockfish populations.

Resumen

En los informes sobre las evaluaciones de las poblaciones de las especies de peces de roca de la costa oeste de Estados Unidos, se menciona con frecuencia la necesidad de disponer de datos biológicos adicionales que proporcionen estimaciones más precisas de la abundancia de la población. La mejora de las estimaciones de población es importante porque esos datos se utilizan para fijar las cuotas de capturas en esta costa del país. La flota de embarcaciones recreativas de alquiler del estado de California ha desembarcado históricamente grandes cantidades de especies de peces de roca; sin embargo, las embarcaciones de esta flota descartan los restos una vez extraídos los filetes de los peces. Estos restos podrían ser una valiosa fuente de datos sobre edad, longitud y sexo, si se utilizara un método de medición estandarizado para relacionar la talla posterior y previa al fileteado de los restos de peces. Para determinar la viabilidad de un programa de recolecta de restos de peces de roca para obtener datos biológicos, se capturaron especímenes de 4 especies de peces de roca en la costa central de California y se midieron antes y después del fileteado. Se estimaron con exactitud las longitudes previas al fileteo con base en la longitud estirada después del fileteo para el rocote azul (*Sebastes mystinus*), rocote amarillo (*S. carnatus*), rocote cobrizo (*S. caurinus*) y rocote bermejo (*S. miniatus*). Un alto porcentaje (87.5%) de los restos tenían gónadas identificables, un resultado afortunado porque la disponibilidad de datos sobre el sexo en los especímenes medidos es una consideración importante para las especies con crecimiento dimórfico. Esta nueva fuente de datos basada en la información procedente de los restos de los peces puede utilizarse para mejorar los datos sobre la talla a la edad y ciclo de vida, disponibles para las evaluaciones de poblaciones u otros estudios biológicos de las poblaciones de peces de roca.

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