METHODOLOGY REVIEW REPORT:
2020 METHODOLOGY REVIEW OF ROV SURVEY DESIGNS AND METHODOLOGIES

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Introduction

A review of remotely operated vehicle (ROV) survey methods and associated data analyses developed by the California Department of Fish and Wildlife (CDFW) and the Oregon Department of Fish and Wildlife (ODFW) was conducted at the National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center (SWFSC) in Santa Cruz, California, on February 4-6, 2020.

The purpose of the Pacific Fishery Management Council (Council) methodology review meeting was to evaluate and review fishery independent visual survey methodologies, using remotely operated vehicles (ROVs), for nearshore groundfish species off the states of Oregon and California (with the potential to guide future surveys in Washington coastal waters, as well). West Coast nearshore groundfish stock assessments have identified the current lack of fishery-independent data sources as a research and data need. Both Oregon and California have conducted ROV surveys of rockfish in nearshore areas, focusing on rocky reef habitat and on areas inside and outside of Marine Protected Areas (MPAs).

The goals and objectives specific to the review of the new ROV survey methodologies are to: A) evaluate the sampling design used in recent (2010-2019) ROV surveys conducted by the states of Oregon and California; B) evaluate proposed methods to develop indices or estimates of abundance from these ROV surveys, including the use of habitat/substrate type, depth, and MPA designation as potential covariates; C) evaluate proposed methods to estimate size/age compositions of observed individuals of each species; and D) identify potential impediments to developing independent indices or estimates of abundance using these ROV surveys and incorporating them into stock assessments.

The meeting was divided into three topic areas for review, with presentations from each of the two states for each topic, plus a fourth discussion topic. The topics were as follows: (1) Generation of video data and survey design; (2) Data aggregation and spatial/habitat relationships; (3) Analytical methods; and (4) Future directions and use in stock assessment.

The Panel commends the Team for their thorough documentation and presentations, and willingness to respond to Panel requests.

TOPIC 1 - Survey Design and Video Data

California

ROV work in California began in 1999. Between 2004 and 2012, ROV surveys were conducted in a number of areas with a focus on MPAs and non-MPA reference sites. Working with Marine Applied Research and Exploration (MARE) and their more advanced ROV, 148 sites were surveyed coastwide in 2014-2016, including MPA and reference sites and other rocky reef areas. Of those, 84 surveyed sites sampled from Point Buchon to Point Saint George were used for this analysis.

The customized ROV “Beagle” used for this survey is equipped with 3-axis thrusters; forward and down ranging sonars; a suite of SD and HD cameras, including forward, down, rear and paired forward; scaling lasers on forward and down-looking camera; altimeters for determining height off bottom; and pitch and roll sensors.

Multiple parallel 500 m transects were surveyed in chosen locations. These were selected from rectangular survey regions (“sites”) 500 m in width that were placed in representative reef areas and roughly parallel to the depth contours, with transects generally on the order of 200-300 m apart. The goal was to cover 4,000 m of rock habitat, and in practice 4-10 transects per site were needed to achieve this target distance. Imagery and data were timestamped at one-second intervals, representing the smallest possible unit of analysis (termed "mircroframes"). Video was used to identify fish to species (in most cases outside of young-of the year) or species group, estimate fish size using the parallel lasers or stereocameras (when possible), as well as to score the substrate. Fish size information was compared to a larger data set from recreational fishing (California Recreational Fishing Survey [CRFS]).

Oregon

In Oregon, ROV surveys have been conducted in five regions containing nearshore rocky reefs in depths of 20 m to between 45 and 90 m (depending on location surveyed), with some sites within regions having been surveyed multiple times. Randomized 500 m transects are used to cover the areas. There has not been a year in which all substantial areas have been covered, nor has the coast been broken into latitudinal sections to be covered in sequential years. Some MPA/reserve site sampling has been undertaken, which would allow for comparisons in densities and trends with non-reserve sites, however, due to the fairly recent initiation of harvest restrictions in those reserves, these distinctions were not considered in the present analysis. Most surveys have been funded by grants or other leveraged soft money. Few dedicated funds have been available to conduct these surveys. Cape Arago, one of the largest areas of hard substrate in the target depth range, was surveyed out to 90 m in 2015, but otherwise surveys have not gone beyond 70 m depth and often have been limited to 45 or 50 m depth.

View area and transect width vary as terrain and ROV height off bottom and pitch vary. These effects are carefully estimated using a combination of camera angles, ROV pitch, and laser measurements. Transect width is estimated for each second along a transect by interpolating from 30-second interval laser width measurements that are smoothed using a 3-point moving-average, which compensates for the fact that the individual measurements at 30-second intervals may vary due to terrain complexities.

Stereocameras have been used to estimate size of fish since 2016, while before that, paired lasers were used. While the stereo-cameras produce more precise sizing estimates, the strict location and angle requirements for obtaining images generally results in fewer fish being measured than with the primary data-collection camera.

Discussion/Recommendations

Sampling should focus on areas of higher biomass and density, with less effort in those areas that have less overall biomass due to lower densities and/or small areas. At the same time, some sampling/information from areas inshore (shallower) and offshore (deeper) than current sampling as well as in sand/mud bottoms is needed for expansion.

There are errors/uncertainties in the location/path traveled by the ROV as well as effort metrics. In particular, determination of swath width is predicated on a flat substrate and there is no way to account for terrain in the width estimates without an independent data source. Despite incorporation of the roll/pitch data into the transect width calculation and an adherence to strict protocols as to when to acquire a laser width measurement, this is likely the greatest source of error/variance in calculating transect area swept. This is unlikely to be solved without an expensive technological solution. Insofar as the impact of swath width error is fairly constant across surveys within areas, this is more of a problem for absolute estimates than for indices of abundance and will result in higher uncertainty in those absolute estimates.

Behaviors vary across species in general and in terms of reaction to the ROV. Some fish do not move except in some case when the ROV is quite close (<2 m; e.g. gopher, quillback, China and brown rockfishes) others are only slightly more reactive (e.g. copper, yelloweye and vermilion rockfishes), while others react more and move across, into, or out of the view of the ROV cameras. The methodologies have been proposed for species whose movements arguably pose little consequence for counts based on behavioral video observations; application to more mobile species would require careful evaluation of the effects of movements. Cryptic species are harder to observe and species schooling in the midwater are largely unavailable to the ROV, but the target species are relatively sessile and observable species that tend to tend bottom. One important function of the ROV surveys is to collect length data to characterize the size/age distribution of the population within the surveyed area. However, relatively few of the observed fish are given length estimates due to difficulties in estimating length due to angle of observation, distance, and so on. This may result in variable/uncertain estimates of size distribution. If there is bias in the size of fish which are available to length (due to varying response to the ROV, for example, or differences in the number of fish that are able to be measured for length when the ROV is at different heights off bottom) there would, in addition, be bias in the length compositions. Research on approaches to estimate lengths (and uncertainty in those estimates) for a larger number of individuals would be useful. This could include how to estimate length for fish at considerable angles to the camera, as well as evaluation of the optimal distance for length estimation. Kline et al. (2014) found relatively small bias (-11% to +21%) in average converted weight estimates from length compositions from recreational fisheries in California relative to those from ROVs, which suggests that the recreational fishery generally sees the same fish as the ROV, for the species considered.

The panel recommended that fish length data were sufficiently valuable to motivate a relaxation of stringency standards and increase sample sizes extractable from ROV surveys. The need to have fish be nearly perpendicular to the ROV to develop a laser-based length estimate greatly restricts the potential sample size. The panel recommended investigation of alternative approaches for estimating length which may be less dependent on fish orientation. ODFW increased its sampling by relaxing requirements for fish to be measured using stereocameras vs. lasers, whereas CDFW indicates that using paired lasers allows for measurements of more fish, though those measurements tend to be biased low relative to stereocamera measurements (Kline et al. 2014).

There are two general categories of potential improvements to ROVs and their operations. One consists of changes to protocols which could improve quantity and quality of the data being collected, species ID, lengths, habitat information, etc. The other is additional technology to improve the quality of the data from the ROV used to quantify area swept. The use of a Doppler velocity log (DVL) system, which could improve location information by accurately logging ROV movement over the seabed, was discussed as one such item. However, a DVL is costly and some ROV systems may not have the data bandwidth to support a DVL, thus the benefit of the technology relative to its expense would have to be considered.

The ROV protocols, data collection and video review methods used by both programs are well-developed and fundamentally sound and appropriate for use in developing indices of abundance.

Future work understanding how differences in methods between the programs affects their respective results would be highly useful to identify some uncertainties and refine methods. Standardizing protocols in ROV operations, data filtering, etc. among the Oregon and California programs as much as possible would useful for comparison and combining of the data sets for species such as kelp greenling, especially if an assessment area spans portions of both states. Analysis of both current data sets with as near as identical protocols as possible in terms of treatment of the data would allow for analysis of how the differences in the current protocols affect the respective results. One way to move towards standardized (as deemed appropriate) and improved protocols in future surveys would be for west coast agencies (including Washington) to hold a workshop to discuss equipment, technology and methodologies for collecting data.

Funding is, of course, a major limitation to this work, both in terms of being able to conduct repeated and consistent surveys to develop indices over areas appropriate for assessment, as well in terms of technology, as ideally all three states would be able to adopt the same technological innovations at the same time.

TOPIC 2 - Data Aggregation and Spatial/Habitat Relationships

California

Data from 4-10 (goal of 8) ~500 m transects at each location are subdivided into 20 m "sample units" or segments. The data is divided into microframes taken at 1-second intervals while the ROV is traveling at a rate of ~ 0.5-0.75 m/s. Unusable microframes (due to backsides, etc.) are removed from transect data. Segments with less than 12 m usable length are removed from data set altogether. Around 8.5% of a little over 10,000 sample units were therefore removed completely from analysis. The alternative approach of using 500 m transects as unit for analysis would not allow for linking of occurrence and abundance to habitat type at a micro-scale level (2 x 2 m cell resolution in a large proportion of areas, though less in some).

The California Seafloor Mapping Program (CSMP) provides seafloor mapping at 2x2 m resolution to 85 m depth, 5x5 m to 250 m depth and 10x10 m resolution to 1500 m, within state waters. The area closest to shore (50-500 m distance) has not been mapped at these resolutions, such that best available data is at 30 m resolution for habitat and 90 m resolution for depth. The analysis of terrain attributes was a balance between the spatial error inherent in GPS (3-6 m), the limitations of ArcTools, and a reasonable expectation of habitat use by rockfish. The 2x2 m cells were grouped by 9 to create 6x6 m cells. Nine of these create an 18x18 m neighborhood encompassing most of the 20 m transect, centered on the transect centroid. A 30x30 m neighborhood area (5x5 block of 6 m cells) was selected as the final unit for the terrain attribute analysis (which can be achieved by aggregations of 2x2, 5x5 or 10x10 m habitat resolutions).

Multiple terrain attributes related to depth, variation in depth, slope, variation in slope and the ratio to surface to planar area are estimated and used in the analyses. Methods to calculate these attributes would be useful topic at a potential inter-agency workshop.

Oregon

ROV sampling in Oregon focused on the 20 m - 70 m depth range, with some areas limited to a depth of 45 or 50 m. The majority of habitat within this depth range in Oregon is sand. However, there are several substantial reefs, notably near Cape Arago and Port Orford. Good multibeam bathymetry exists for most of this area, except for the area south of Port Orford in the vicinity of the Rogue River. Detailed habitat data and ROV survey data are lacking for that section of the southern Oregon coast.

The dataset categorizes primary (“Lith1”) and secondary (“Lith2”) substrates, which are combined into a single mixed classification (“Lith3”). Lith3 was used for survey design and data expansion, with Lith3 habitat types aggregated into seven categories. ROV habitat observations were not used for abundance expansion as they are intrinsic to the video; habitats as assessed directly by the ROV represent higher resolution observations than the available mapped habitat data and are thus not able to be directly expanded using the lower resolution habitat maps, but are particularly valuable for ground-truthing the habitat models/maps. There is an unknown degree of subjectivity in the “Lith” categories as there is variation in data quality and ultimately these classifications are made via human judgment. Similar to the approach for California, data was aggregated with a goal of 20 m segments. In contrast to California, each segment was required to be entirely within one substrate category, such that a segment ended and a new one began when there was a change in assigned category. Thus, many segments were shorter than 20 m. Similar to California, a minimum size cutoff (in this case 10 m^2 area) was used to exclude small segments.

A substantial amount of time was spent discussing the appropriate scale at which to analyze ROV transect data. This included considering the consequences of defining the entirety of each ROV transect as a sampling unit versus using subsections of a transect as a sampling unit. Such considerations are important for determining appropriate methods for dealing with spatial autocorrelation and uncertainty in the analyses.

While the segment-scale data was used for exploring substrate category specific species densities and other purposes (habitat suitability models not included in the report), abundance estimates calculated at the reef scale utilized data at the transect level. Ultimately, analyses and expansions were conducted with all habitat classes representing rocky reef combined into a “hard habitat” layer, while alternative analyses included full transect with expansion including a soft-bottom buffer area around hard-bottom categories. Regional abundance from either of these analyses could be summed to get coastwide estimates by depth range to avoid the issue of trying to expand across the entire area given different levels of habitat mapping resolution.

Discussion/Recommendations

<u>Overall</u>

Coverage of, or methods of expansion to, the full suite of habitats and depths occupied by target species outside of the survey data is needed if absolute estimates of abundance are desired. For indices, understanding of the suite of habitats and how the proportion of biomass observed might vary across surveys is also useful. Both programs should continue to consider if it is practicable to expand the survey design, and how to best approximate biomass (and its uncertainty) in unsampled strata.

Investigation of impacts of different levels of specificity in habitat designations, where available, to determine habitat relationships may reveal whether the additional effort to include more detailed habitat information both for observations and expansions would provide for better and more precise abundance estimates, and where the greatest gains could be made. For example, there are areas of missing or low-resolution mapping data shallower and deeper than the core area surveyed by ROVs to date. If these areas are important to a species, this may lead to more uncertainty in biomass estimates. Consistent designation and delineation of hard bottom vs. soft bottom habitat is needed for consistent data expansion. Validation of habitat designations using ROV scoring to compare to polygon or segment habitat designations would also provide more information on accuracy and variability.

Direct evaluation of how segment scale affects linkage to covariates and segment species abundance observations (and possibly size distribution) could provide more information on the value of using the 20 m segments vs. full transects.

The issues of habitat designation, linkage of survey segments to habitat, scale of analysis, and expansion could be included on the agenda of a potential west coast states workshop, as suggested in Topic 1. Another issue which should be addressed is data storage, database structure, and accessibility. A centralized, well maintained, and easily accessible and interpretable database would aid in both availability and ease of analysis of this data. A formal description of how the data will be made available and the form it will take would also be helpful.

California

CDFW considered the tradeoffs of defining the entirety of each ROV transect as a sampling unit versus using either 20-m segments or microframes as the sampling unit. They determined 20-meter segments would provide the best linkage to the scale of habitat information available and the location accuracy associated with the survey track. The California report outlined a number of important considerations in determining to use 20 m segments, which are compelling. Further analysis as well as comparison of abundance estimates when using 20 m segments versus full transects could provide more support for using smaller segments while also determining the impact of using the alternative full transect scale on the final numbers.

In California, north of Point Conception, the highest density coverage by the ROV relative to total area is in the 20-70 m depth range. There is substantial coverage from 20 to 100 m, moderate coverage in the 10-20 m and 100-110 m depth ranges (~10% of the coverage for 20-70 m), and sparse sampling beyond those ranges. Most target nearshore rockfish species are seen in relatively small numbers beyond 100 m, and other sources of data exist in those depths for those shelf species that do extend substantially into those areas. For shoreward areas (0-10 or 0-20 m), CDFW has suggested extrapolating from the next shallowest depth stratum or using data from such as the PISCO dive survey. Direct information would provide the most confidence, particularly where substantial proportions of observations are seen in the 10-20 or 20-30 m zones, as with gopher rockfish and kelp greenling, but where ROV sampling in shallower depths does not take place due to logistical, visual and safety issues.

Development of design-based biomass abundance estimates derived from full transect data that are similar to the current design-based analysis would be useful for comparison to the current analysis and to the analysis for Oregon.

Oregon

Surveys extended from 20 m out to between 45 and 70 m in Oregon, missing the shallowest and deepest strata where many species occur, given that hard substrate habitat exists at those depths. Multibeam bathymetry is lacking for areas of the south coast and is needed prior to any ROV survey in those areas.

Development of design-based biomass abundance estimates derived from 20-m data similar to the design-based analysis from California, in regions where possible, would be useful for comparison to current analysis and to the analysis for California.

TOPIC 3 - Analytical Methods

California

Abundance was estimated using two approaches. A "design-based approach" relied on a generalized linear model (GLM) to identify variation in density with depth, latitude and proportion hard substrate, and inform the stratification used. For gopher rockfish, a generalized additive model (GAM) was used, with the addition of CSMP seafloor relief data, to estimate the relationship between the covariates and density informing model-based estimations of biomass.

Abundance estimates have been based on extrapolating densities based on habitat area by California Seafloor Mapping Program (CSMP) data sources using design-based methods. Model-based methods are analogous to Young and Carr (2015) and Dick and Xi (2019, cowcod assessment), and expanded using the Marine Geospatial Ecology Toolkit (MGET) described in Roberts et al. (2010) to produce density and abundance estimates over broader scales. Both approaches provide estimates of numbers of fish, which are then converted to biomass based on length frequency data.

Species considered were limited to those whose depth range were largely covered by the sampling, nearshore species in hard bottom habitat. In particular, analyses focused on china, copper, gopher and vermilion rockfishes and kelp greenling and secondarily on brown and quillback rockfishes, for all of which it is possible to produce absolute estimates of abundance for consideration. It may be possible to produce usable indices, but not absolute estimates, for blue and deacon (BDR), black, canary, and yelloweye rockfishes, as well as for lingcod.

To develop density estimates and indices of relative abundance, CDFW used generalized linear models, exploring Poisson, quasi-Poisson, negative binomial distributions, as well as binomial distributions for presence-absence. As described above, transects were subdivided into 20-meter segments as a unit of effort, with a criteria that at least 60% of the distance and area of that segment had to be sampled/observed for the sample to be used. Total sample sizes post-filtering (for matching habitat attributes, etc.) were reported, together with covariates that were evaluated (ROV derived variables, effort variables, ROV and CSMP derived habitat variables and CSMP only derived habitat variables). Models also evaluated the effort components (width, distance, time), used correlation coefficients and AIC stepwise backward selection (as well as deviance) for model selection. Negative binomial and zero-inflated Poisson distributions tended to provide best fits. Depth, latitude and proportion hard bottom were commonly significant in GLM analysis.

Oregon

Analytical methods used by the Oregon Department of Fish and Wildlife to estimate fish densities from ROV surveys and to expand them to estimate regional and total abundance of nearshore fish species were presented. To expand from transect level data to total estimates of abundance, both design-based and model-based expansions were developed. For both approaches, data summarized at both the segment and full transect scale were explored. Each transect was divided into seven substrate types – derived from available seafloor mapping information – and total counts for each species were produced with respect to each substrate type. These seven substrate types were then further collapsed into two categories: hard (substrates of cobble and larger grain sizes) and soft (substrates with grain sizes smaller than cobble). While some preliminary analyses on densities of fish with respect to individual substrate classes were provided, the focus in subsequent analyses was on information for the hard and soft categories at the full transect level. Data at the segment level provide the opportunity for future work relating fish density and finer scale habitat attributes.

For design-based expansions, average densities were calculated for a few example species (kelp greenling, lingcod, yelloweye rockfish) and these estimates were expanded to the total rocky habitat areas at the site, region, and statewide scales. It was demonstrated that a range of decisions about defining what is hard vs. soft substrate have important consequences for estimates of total abundance.

Model-based analyses resulted in models that use the total count for each transect (with only hard substrates included) with terms including an effort offset, location (as a factor), depth (smoothed), and a depth-by-region interaction (smoothed) with a negative-binomial likelihood. Diagnostics demonstrated this to be a reasonable and appropriate statistical model. Variance estimates associated with the estimates of total abundance relied on a resampling approach. While assuming that the estimated coefficients were approximately multivariate normally distributed, 10,000 samples were drawn from the coefficient distribution. For each draw, the density was expanded to all hard substrate locations and then summed to generate an abundance for each draw at the site, region, and state scales. In aggregate this produces a distribution of total abundance estimates which can be multiplied by the average weight of individuals to yield biomass. For each example species, the total number of fish estimated across design and model-based methods was on the same scale as estimates available from recent stock assessments. For kelp greenling, for example, the design and GAM-based estimates were in the range of 700-800,000 individuals, while the 2015 assessment (Berger, 2015) estimated a population size of 316 mt, equivalent to approximately 500,000 individuals.

Models that included spatial autocorrelation were also considered. When the data were summarized at the transect level, examination of variograms and other spatial statistics did not seem to provide strong motivation for using spatial models. Results from VAST were not obviously superior to non-spatial fits, suggesting there was not much value in including the spatial model components under current levels of data aggregation.

Oregon used fairly stringent criteria for when fish lengths could be extracted from the video when relying upon paired lasers, resulting in very low sample sizes for some species. Sample sizes have increased since 2016, following the switch to stereo video for this purpose, though still rely on those fish which are both close enough and at a proper angle for measurement.

Discussion/Recommendations

The panel discussed the potential impact of missing the tails of the density distributions by not including habitats that are generally softer bottom, including areas that border hard bottom habitats, as well as shallower and deeper areas than those currently covered. The impact depends on the potential area to which those densities would apply (how well the core depth and habitat areas for a species are covered by the survey) and the way in which the information from the surveyed areas will be used in assessments (i.e., relative indices are robust to bias in observations or expansions, and can still provide valuable information if informative priors could be developed for catchability coefficients, other information allows for reasonable estimates of catchability, or "absolute" abundance indices could be developed using other or additional data.

It is clear that detailed protocols for defining the area to which the total abundance is expanded are necessary for estimating total abundance. The definition of habitat will likely need to be carefully examined on a species by species basis. Additionally, the distribution of rocky habitat is clearly non-uniform in Oregon, with a few sites (Arago, Port Orford) dominating as a proportion of total rocky area in the state. It was noted by the panelists that some caution is needed when interpreting estimates of total abundance based on surveys that are not stratified and sampled with a pre-defined design.

The Panel discussed the approach of removing survey segments for which large portions are not useable (e.g. less than 12 m length (California) or 10 m^2 area (Oregon) usable are out of a 20 m segment) from the data set used for analysis and recommends not throwing away data from small swaths, noting that the nature of the observed correlations is inevitable as you "create" additional zero observations. In general, the Panel agreed that retaining these smaller segments should not introduce bias, but rather would lead to some additional "noisiness" in the data and may also complicate matching to terrain attributes. This data remains valuable, and considerable effort has or will be expended in determining the usable data within each segment or transect.

Comparison of biomass estimates when using different spatial scales of analysis (e.g. 20 m vs 500 m segments) should be undertaken, with the goal of determining how much these estimates vary from each other and if there is a consistent bias between the two approaches within or across species. There may be greater value in using a spatially explicit model when data is maintained at the segment level and there is more fine-scale spatial information retained. However, the value of using this scale of analysis should be evaluated relative to larger segments and more general habitat designations, at least in terms of overall biomass abundance estimates. Given differences in habitat characterization methods between Oregon and California, and variation in resolution of habitat maps, more general habitat designations would be more consistent across space. Until we have more consistent and high resolution mapping as well as understanding of fish behavior and distribution and both seasonal and environmental relationships, development of more detailed habitat relationships will be difficult. Adequate representation of covariates in sampling design is needed for either design or model-based estimates.

<u>California</u>

To evaluate detection probability with varying swath widths, CDFW also explored density with swath width from 1.5 to 3.5 meters (sample size over ~4 m swath is very low) to identify cutoffs for usable segments. They also explored questions related to relationship between density and height off the bottom and found strong correlations between densities and height of the ROV, but noted that this could be expected as ROVs are flown higher over more rugose habitats. Analysts should ensure that a preponderance of zeroes does not result in low variability measures. Analysts should also ensure that cutoffs for swath width or exclusion of segments based on segment length do not affect the number of lengths, or the proportion of observed fish for which lengths are available, as this would have the potential to result in some bias in length compositions.

Oregon

How to model between and within-reef variation in abundance relationships to habitat and depth should be explored. This should include a rigorous analysis of spatial autocorrelation and consideration of geospatial analysis of the survey data. While the Vector-autoregressive spatial temporal model (VAST) was applied to the Oregon data, and may be useful in, for example, combining data across years, more exploration of that tool and others is warranted. Spatial analysis can help define potential break points for assessment areas and provide for more informed expansion.

REQUESTS:

1. For California, information on site by site variation in density, i.e. small-scale location level variability for one or two species could inform appropriate level of stratification. This would include plots of summaries average density by site N to S.

Response:

Note that a “site” refers to a set of transects, and a “location” refers to a group of sites in the same area.

In California, there is a clear trend for gopher rockfish with higher densities in the south; a threshold latitude for kelp greenling, with less in the south; and a fairly random pattern for vermilion, with some evidence of a bit more in the south. Random site or location effect is needed for analysis in all three cases. May need to aggregate to a level where the model is stable due to areas of zeroes.

2. Write down the equations describing expansions for design-based and model-based approaches. This is to understand the small variances reported. Note that a longer segment length will give you lower spatial autocorrelation.

Response:

Equations provided multiplying by area and weight to get scale of biomass were correct, but for variance these should have both been squared. These were corrected.

A further note is that one would want to drop the effective sample size to account for spatial autocorrelation if present.

Future Work:

A. Surveys are focused on rocky habitat, but there are large areas of soft habitat. What are the potential numbers in those areas and how might they change as the population increases?

Both states have some information from soft-bottom habitat around the hard substrates. Are there benefits of continuing to survey some of areas with subprime habitat both in areas around hard substrate areas and elsewhere to provide a more complete picture (e.g. occurrence and densities in these areas, shifts in habitat with climate, increases in densities e.g., in MPAs as population expands)?

B. Investigation of how the habitat mix observed by the ROV relates to the habitat mix associated with each (20 m) segment would provide information about the accuracy and precision (or amount of small-scale variability) of the habitat classification. This would include a review of how the filtering to hard habitat in the survey compares with what is considered hard habitat from mapping – i.e. do they match up in terms of how much of what would be classified as soft habitat is included and how much hard habitat might be excluded due to error, scale of mapping/observation, of other factors.

TOPIC 4 Application in Stock Assessments and Management

The panel discussed potential use of ROV survey data in stock assessments of nearshore rockfishes. The applicability of current or future data collections will depend on how that data would be used. Information from the surveys which could be used in stock assessment include both abundance and length composition data and associated measures of uncertainty. Abundance data can be considered either as a time series of relative indices or as absolute estimates of abundance for the portion of the population observed (or "selected") by the survey. Good estimates of survey selectivity depend upon length data, as smaller individuals, for many surveys, are less likely to be observed (or, for ROV surveys, identified to species). For abundance and composition data, the coverage (latitude, depth ranges and reef area relative to total), intensity and frequency of sampling will greatly influence the value of the surveys.

Since the distribution of habitat and therefore abundance across the coast is highly uneven, surveys should focus on the areas of greatest habitat/abundance, while smaller, more difficult or time-consuming areas to survey with less expected biomass could be visited infrequently and their biomass contributions included in the catchability adjustment or estimated from occasional surveying. Data from soft-bottom areas surrounding as well as far from hard-bottom habitat can provide either evidence of the absence of certain species from soft-bottom habitat or expansions for those habitat areas.

Neither state has sampled the appropriate habitat in a single year for either the entire state or for each complete typical assessed area (which can be sampled in separate years). There are generally two approaches available for using data that covers only a portion of the range of a stock in a single year. These are:

1) Combine multiple years of data into a single "super year" index or absolute estimate of abundance. This is most appropriate for longer-lived species and if we have good information that (a) individuals within a species generally do not move long distances (e.g. between reefs), and (b) the data was collected across a few (e.g. 2-3) years.
2) Conduct assessment over smaller areas that can be covered in a single year. This involves either completely separate assessments assuming no connectivity among areas, or a single assessment within multiple areas with the assumption of low movement rates among areas. Tagging data can support that assumption.

Both approaches are potentially appropriate for the relatively sessile species which are the main targets of these surveys.

For each target species, analysis of the appropriate scale(s) for assessment and the adequacy of auxiliary data at each scale for assessment should be undertaken, and this information could inform both future survey operations and use of survey information in assessments. Where the vast majority of depth range, habitats and latitudinal range for an assessment is covered, absolute abundance estimates are possible. Calculation of a selectivity function, analysis of uncertainty in catchability, and corrections for depths outside the core depths surveyed are needed in that case. Indices of abundance could be used for species where less of the depth range is covered, though without auxiliary information, selectivity would be more uncertain in those cases.

California

The panel agreed that the data collection efforts were effective at providing information on abundance in the areas surveyed for nearshore species, and can provide absolute abundance estimates in surveyed regions or latitude ranges for species where nearly all of the depth range and habitats are covered by the survey.

Common assessment areas within California include the area south of Point Conception, the area from Point Conception to Cape Mendocino, and the area north of Pt. Mendocino, which could each be completed within a given year to provide a year specific estimate every few years for each assessment area. The timing of the northern area could be coordinated with the survey in Oregon, or the southern portion of it, to provide synoptic surveying allowing direct comparisons between regions and more coherent modeling over a continuous area. Stratification accounting for potential differences in onshore and offshore densities in the Southern California Bight may be worth examining. Ideally, this will be possible to achieve in future years, though it requires adequate funding, staff and equipment. Current data includes latitudinal areas covered over three years from the Mexican Border to the Oregon border, and this data could be used to assess those separate areas or be combined into a single super-year.

Current data includes three distinct latitudinal areas were covered over three years from near Point Conception to the Oregon border, and this data could potentially be used to assess those separate areas or be combined into a single super-year.

The CDFW report suggested appropriate use of biomass abundance measures in assessment. These include use as A) Indices of relative abundance, B) Absolute estimate of abundance to be used in stock assessment or directly in management when coupled with F_{MSY} proxies, and C) as relative measures for use in area allocation of catch limits. They provided a suggestion for the potential use of the survey data for various species in Table 2 of their report. The methodology review panel agrees that there is potential for the following uses by species:

A) Indices of relative abundance or as relative measures for allocation
   - i) As constructed: Brown, China, copper, gopher, quillback and vermilion rockfishes and kelp greenling.
   - ii) With further analysis/auxiliary information due to more extensive depth range: Yelloweye rockfish and lingcod.

B) Absolute estimates of abundance

With expansions: Brown, China, copper, gopher, quillback and vermilion rockfishes and kelp greenling.

Black, blue/deacon and canary rockfish may be candidates for developing indices if ROV data is coupled with other observational data given the tendency of these species to be found in midwater or off-bottom schools.

Oregon

The original design of each separate ODFW survey was a randomized design targeting each separate region, rather than being focused on providing data to incorporate into stock assessments, although current data could be combined to provide information on the scale of the population. For some species, data from the combined surveys could be used to create a single aggregated across-time abundance estimate assuming no changes in abundance over time, thereby providing a general scaling of biomass, limited to the depth range considered.

Data was collected over several years (2010, 2012 and 2015-2019), and not according to distinct and complete latitudinal divisions, so that either combining all data into a single estimate or splitting into multiple areas is more problematic. Depth ranges were inconsistent among areas and years, and do not generally cover near the entire depth range of any species. However, with appropriate uncertainty measures (to be investigated) a single abundance measure for the surveyed portions of the Oregon coast could potentially be used as a general indication of the scale of abundance for the surveyed depth ranges over the period sampled. This could provide, for example, a prior on biomass for use in assessment. While one could investigate tradeoffs in survey design across years when using super-years or developing biomass priors, the needs of species with area assessments likely supersede any benefit of survey designs other than simple latitudinal divisions. Investigation of the proper latitudinal divisions that will adequately meet needs across species is needed for future survey design.

Clear proposals on how to address such data/information gaps where they exist would aid in determining potential for incorporating ROV data into stock assessments where depth range extends substantially beyond the survey frame or inadequate length samples have been collected.

In particular, information on the (average) portion of each stock missed by the surveys would be needed to develop absolute estimates of abundance as well as to provide additional information to validate survey selectivity estimates.

Other Topics

The panel agreed that ROV surveys have the potential to be very useful for stock assessment for certain nearshore and shelf species. Surveys dedicated to providing information for stock assessment, and associated increased habitat mapping efforts, could provide more complete and consistent information for this purpose. This will require dedicated resources for these surveys, including access to vessels, ROVs and funds, as well consideration of potential technical improvements and ways to gain more information (such as more length estimates) from the video data. Other data collection goals for these surveys (e.g. ecological data, surveying biomass in rockfish conservation areas, sampling deeper depths to increase coverage of species of interest, inside/outside MPAs, etc.) should also be considered in order to optimize/balance overall data collection.

The k-fold validation work undertaken by both states shows moderate variation within the surveys. There is additional validation work that should be undertaken. This includes inter-agency cross-validation of species identification, counts and length data to ensure consistency and identify issues or uncertainties that can be addressed. Validation of expansion methods and determination of overall uncertainty can be further addressed through prediction of density/abundance of both previously surveyed and non-surveyed reefs using data from other areas and/or years and comparison to observations. This should include efforts to validate the ROV survey biomass estimates and other biomass information at the site scale, including comparing to other data (e.g. CRFS catch data), ensuring that sampling occurs in predicted high density areas for target species, and confirming low density of target species on soft bottom habitat.

Key Recommendations

- Hold a workshop among the three state agencies (with invitations to Alaska and Canada) to promote further development and harmonization of field and analysis methods.
- Plan and complete model and inter-agency validations and calibrations.
- Define dedicated survey objectives.
- Identify and secure dedicated funding adequate to meet objectives.

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Partial List of Attendees

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Alan Williams, CIE
John Budrick, CDFW
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Joe Bizzarro, SWFSC
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Tom Laidig, SWFSC
Andy Lauermann, MARE
Dayv Lowry, WDFW
Rick Starr, MLML

Appendix A: Detailed, if not necessarily complete, List of Potential Future Workshops and Improvements

- Hold a workshop among the three state agencies (with invitations to Alaska and Canada) to promote further development and harmonization of field and analysis methods – primary topics of this workshop could include:
    - Defining consistent, generalized habitat classifications (lowest common denominator) that can be used interchangeably by WA, CA, and OR in a coast-wide stock assessment process – note that this does not preclude the use of more specific (i.e., higher-resolution) habitat variables for state-specific or other modelling needs/analyses
    - Evaluation of video review methods and technologies (sharing video data and analysis software between agencies for independent processing).
        - What are the strengths/weaknesses/limitations with each process?
        - Is one process better than another?
        - Are there new software/hardware tools available?
        - Inclusion/exclusion of data (e.g., backsides, off-bottom, etc.)
        - Can methods (or should they) be standardized across agencies?
        - Reviewer variability – confidence in species and substrate ID's, length estimation
        - Technological improvements (e.g., automated object recognition and tracking?)
        - Detection probability
    - Discussion of analysis techniques and model variables. For example, some terrain attributes, like rugosity – ratio of surface to planar area, can be derived in several different ways and can produce slightly different results. Depending on how it is derived, a particular terrain attribute may or may not be significant in a model, thus identifying a consistent set of terrain variables and derivation algorithms is important for developing a consistent framework for the west coast. These attributes can also be derived at different scales, so a common scaling factor will also be important for maintaining cross-agency consistency.
    - ROV equipment and protocol improvements/modifications/calibrations
        - Stereocameras and analysis software

          Doppler Velocity logs (DVLs)
        - Equipment/vessel sharing?
            - For example, WDFW deployed their ROV from a Canadian research vessel in 2018 with minimal modifications to the system
    - Data storage and handling

- Plan and complete model and inter-agency validations and calibrations
    - Each agency uses different methods to calculate transect length and area swept, thus understanding how each of these methods compares would be a good starting place for validation work (e.g., editing of tracking data and trackline smoothing methods). Is 1-second width estimation needed?

- Comparison and evaluation of terrain attributes (see Workshop sub-bullet above)
- Comparison and evaluation of video review methods and analysis (see Workshop sub-bullet above)
- Evaluation of optimal transect/segment length (e.g., 20m vs full-transect)
- Sharing of video data for inter-agency comparison of identification, counts, lengths, etc.

- Define dedicated survey objectives
    - Priority species
    - Absolute vs. relative abundance estimates
    - Level(s) of precision (species/group specific?)
    - What survey design(s) are most appropriate for the identified objectives?
    - Should ROV surveys be used to “in-fill” gaps in surveys where ROV target species also occur on trawlable habitats rather than surveying all habitat types for those species?
    - Given that ROV surveys are more logistically challenging than trawl survey, where can we achieve the biggest “bang for the buck?”

- Identify and secure dedicated funding adequate to meet objectives (i.e. for needed frequency and coverage of surveys)

PFMC
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