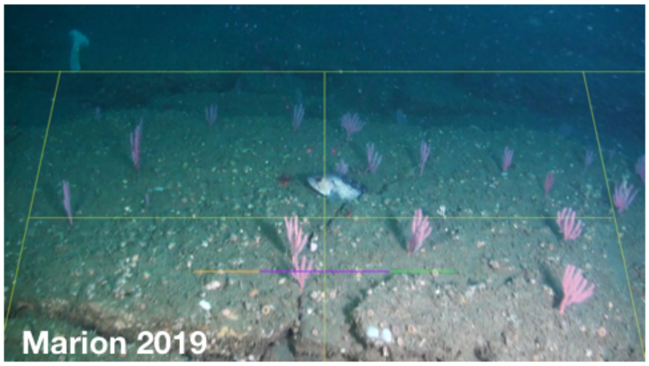
Dr. Arthur Trembanis

NOAA NMFS
Center for Independent Experts (CIE) Program
External Independent Peer Review

Remotely Operated Vehicle (ROV) Surveys of Nearshore Stocks - California & Oregon

Pacunski et al., 2016



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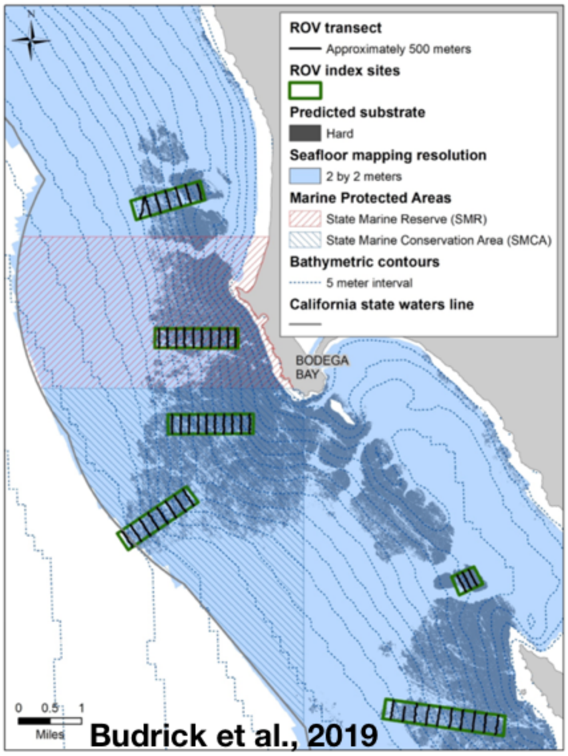


Budrick et al., 2019

Executive Summary

At the request of the NOAA NMFS CIE Program an independent technical peer review of the OR (ODFW) and CA (CDFW) ROV based fish survey research programs was performed to evaluate the strengths and limits of photographic, videographic and integrated geoacoustic habitat mapping as well as associated platforms and post processing of seafloor and water column images as part of the inshore fishery monitoring strategy. The review was conducted based on the provided reports and relevant publications and informed by additional comparison to previous and ongoing programs of similar design in other parts of the country. The review focused on three major thematic topics: 1) describing the different ROV imaging systems including field survey design and data analysis; 2) strengths and weaknesses of these systems and survey programs; 3) future directions of imaging technologies and strategies. These topics were examined through the direct assessment of specific terms of reference (ToR) provided to the reviewer. The overall findings are that both the OR and CA programs are utilizing sensors and platforms that are considered state of the art and employing best available practices with regards to sampling design and field survey execution. Areas for improvement and programmatic growth are identified that include cataloging data into discoverable database structures and integrating available machine learning community tools for automated detection of targets within imagery and video.

Background

The National Marine Fisheries Service and the Pacific Fishery Management Council is seeking a desk review to evaluate and review fishery independent visual survey methodologies, using remotely operated vehicles, for nearshore Groundfish species off the states of Oregon and California.

West coast nearshore groundfish stock assessments have identified the current lack of fishery-independent data sources as a research and data need (PFMC, 2017, Agenda Item E.2, Attachment 1, September 2017). In addition, methods currently utilized in stock assessments do not explicitly account for differential biomass densities inside of no-take Marine Protected Areas (MPAs). Remotely operated vehicles (ROVs) provide a non-lethal sampling method in areas where harvest is prohibited. They also allow collection of data on overfished species and nearshore species that constrain take of healthy stocks. Because ROVs employ only non-lethal data collection methods, they avoid the need for research catch set-asides or other allocative considerations that may arise between fisheries and research sectors.

Both Oregon (ODFW) and California (CDFW) have conducted ROV surveys of rockfish in nearshore areas, focusing on rocky reef habitat, and, in California, on areas inside and outside of MPAs. In both states, resultant information includes density estimates (by transect and habitat) for various species and length data. In addition, the states have developed seafloor maps, allowing estimation of area of habitat types by depth and latitudinal breaks.

Density estimates can be developed in a number of ways, from simple extrapolations to more complex general linear models (GLMs) and generalized additive models (GAMs), including factors that may affect detection probability across sample sites. There is likely to be differential detection by species, gender and size, and by timing of survey as well.

Observed density estimates and indices of relative abundance or estimates of absolute abundance in the depth and latitudinal areas surveyed can be used in stock assessments, given appropriate accounting for selectivity and detection probability, or potentially used in management procedures. Length composition data collected by the surveys may be included in stock assessments or management procedures as well.

Problem Statement and Reviewers Background

Human reliance upon and extraction from pelagic and benthic ecosystems necessitates an understanding of the spatial extent, structure, and function of these ecosystems. This report conducted a review of the California (CDFW) and Oregon (ODFW) West Coast ROV (Remotely Operated Vehicle) based programs engaged in using these robotic platforms for remote benthic habitat mapping and fisheries studies. This review examined reports and primary literature in order to assess the full scope of the program activities from experimental design, field implementation, imagery post-processing and data analysis. Comparisons are drawn from the similar programs nationally and internationally and from the reviewers own experience employing both traditional technologies for wide area coverage (towed side-scan sonar and hull mounted multibeam echosounder) to combined studies with point sampling and new technologies (AUVs and ROVs) for gathering data in an unprecedented level of resolution over targeted regions of interest.

Digital photography/videography is becoming the technology of choice to document macrofaunal seafloor habitats and demersal fish communities. The ability to record and inspect a large number of images while still in the field has made image sampling much more efficient, and allowed significantly larger sample sizes, when compared to the days of film. In addition, traditional sampling, using quantitative grabs and/or dredges, is still necessary to ground truth images with actual specimens, and sediment samples, but can be based on near real time inspection of imagery. In short, traditional grab sampling, by itself, is conducted on too small a scale, and requires too much extrapolation, to adequately characterize benthic communities and habitats on the scale that would reflect climate change or on the scale required for the management of offshore development efforts.

Recent mapping that we have conducted on similar prior projects to this proposal (Trembanis et al., 2012; Miller et al., 2010; Raineault et al., 2012) have convinced us that, in general, shallow coastal ecosystems are far more complex and heterogeneous in bottom type than typically anticipated. Furthermore, conventional sampling by direct methods (i.e., bottom grabs or dredges) is also generally recognized as severely limited by several factors including gear bias, spatial averaging and limited sample density. It is only from the careful fusion of multiple technologies (i.e., ship-based, ROV, AUV, grab samples, and dredge) that one is able to compile a holistic picture of the nature and composition of the benthic and water column habitats (Miller et al., 2010; Raineault et al., 2012; Raineault et al., 2013).

Admittedly, visual imagery has its technical limitations, but the numbers of photographs, and consequently the amount of quantitative data that can be generated on a single cruise, far exceeds that of grab or dredge-based sampling. Indeed, one of the major issues facing the use of visual imagery for sampling is how best to deal with the resulting terabytes of available information. Although machine vision promises to automate the assessment of visual images, and is achieving success for single species such as scallops, the techniques are still in development and require more annotated image databases to create the necessary post processing tools for comprehensive survey of diverse marine fisheries communities.

Dr. Art Trembanis is an Associate Professor at the University of Delaware, director of the CSHEL Lab, and co-founder of the Robotics Discovery Laboratory. Dr.

Trembanis received his undergraduate degree from Duke University (1998), was a Fulbright fellow at Sydney University (1998-1999), received his Ph.D. from the College of William and Mary (2004) and was a post-doc at the Woods Hole Oceanographic Institution (2004-2005). He also worked previously in the oil and gas sector (Anadarko) and AUV industry (Sias Patterson Inc) as a geophysical scientist and software engineer where he helped to integrate a fisheries sonar and stereo camera for an AUV system for the SWFSC Advanced Survey Technologies Group.

Dr. Trembanis has over 18 years of experience working with autonomous underwater vehicles (AUVs) and other oceanographic field robotic systems (ROVs, USVs, UAVs). His work entails collaborative exploration of the oceans integrating geological, physical, biological, and chemical oceanography from estuaries to the outer edge of the continental shelf.

Since 2011, Dr. Trembanis has engaged in optical AUV based surveys of the sea scallop *Placopecten magellanicus* to determine size and abundance distributions to assist in stock assessment monitoring. This work has entailed developments in approaches to analyzing and managing large image datasets and has included creating deep learning convolutional neural networks for the rapid detection and sizing of sea scallops.

Other ongoing topics of interest include combined geoacoustic and optical approaches to mapping mesophotic coral reefs to studies of shelf and estuarine benthic habitats, scour processes associated with shipwrecks, artificial reefs, and the detection of unexploded ordnance (UXO).

Summary of Findings

Terms of Reference (ToR)

ToR 1) **Evaluate the sampling design used in recent ROV surveys conducted by the states of Oregon and California, addressing the following:**

a. Are sampling designs appropriate

   i. To develop estimates or indices of abundance by species in the surveyed areas

   ii. To estimate size composition by species

   iii. To expand these to areas outside of the those surveyed

   iv. for use in assessment models as indices of abundance or otherwise, or for use in management procedures?

b. Recommendations/suggestions for improvements to sampling designs

Review of ToR 1

The sampling design of Oregon ROV program between 2010-2018 utilized randomly placed 500 m transects with survey regions selected based on a statewide Surficial Geologic Habitat map. Transects were constrained to a shallow water limit of 20 m based on operational considerations. Offshore depths varied from 45m to 90 m depths and were set by considerations from the background mapping data and additional constraints such as presence of kelp forests and critical habitat areas. Transects were then randomly (with a few exceptions) selected within these stratified survey corridors. In the 2010 survey of the 134 attempted transects 125 produced usable quantity data (specific reason not listed) for a yield of 93%. In 2016 a subset of transects from the 2010 survey were reoccupied (to within approximate location based on navigation and handling) and limited in number by project funding.

The stratified random survey site selection is a strength and commonly employed approach. The basis for the 500 m transect length is not really well established here and should be examined further through auto-correlation analysis of both the habitat mapping data and the fish abundance data. Is 500 m more than is needed in which case transects could potentially be further subdivided to increase aggregate sample numbers? Is 500 m too short to fully capture a domain in which case longer transects will be needed? There are examples from the sea scallop survey program that consider these questions of transect design and length. Perhaps these experimental design issues have been worked out previously and are well known to the program teams and simply were not reported here. The Cape Perpetua surveys would seem to be a good set for testing the transect length as the dives were run over 1.6 to 2.1 km and can thus be subset at varying length intervals to assess how transect lengths affect the resulting abundance estimates. Additionally efforts could be made to process sub-segments using a sliding box time window in order to reduce edge effects from segmentation.

The sampling design of the CA ROV program between 2014-2016 visited 148 sites at which 4-10 transect lines were surveyed to achieve 4 km of transects within each site selected based on a state-wide California Seafloor Mapping Program (CSMP). Offshore depths with reported observations varied from 10m to 230 m depths. Transects were executed with the Beagle ROV utilizing heading, speed, and altitude autopilots to constrain the vehicle dynamics and the ROV positioning was tracked using an acoustic USBL. Stereo camera paired with parallel forward pointing red lasers for fish sizing were also informed by two 500 kHz ranging sonars used to measure the horizontal transect width. ROV tracked position and sensor data were recorded directly by HYPACK® and utilized to register positioning for the ROV and the video and still frame images taken during the surveys.

ToR 2) **Evaluate the video and data processing tools/methods and methods to determine total area surveyed for each transect.**

a. Are methods scientifically sound and robust?

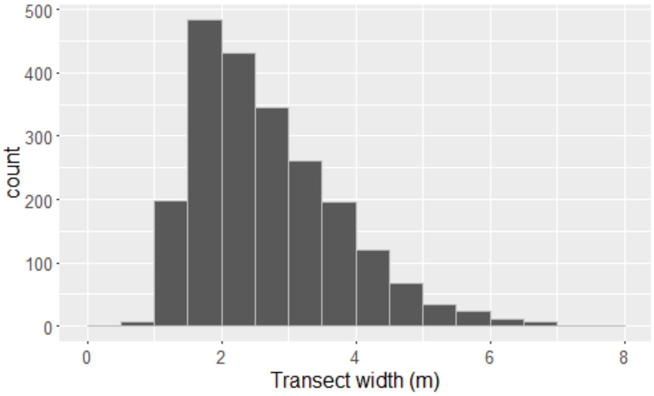
b. Are the methods appropriate for the available data?

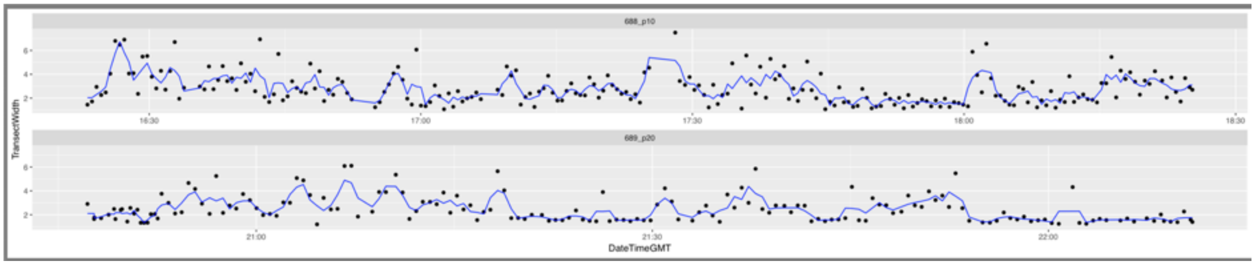
c. Recommendations/suggestions for improvement to methods.

Review of ToR 2

The data processing tools and methods used to determine the survey area involve converting transect length into area coverage based on image width across the seabed. This requires that the seabed is visible within the image and that the altitude variability can be accounted for as this in turn varies the image width.

From the Oregon survey report a nice set of summary plots were presented illustrating the variability in the transect width both in bulk population histogram and in time series along a transect line. The variability within a transect as the ROV adjust to changes in depths and vehicle dynamics (caused by things like cable pull, currents, waves, and thruster motion) illustrate the differences in transect width that have to be accounted for with each count estimate to convert to abundance of species per m^2. Total area surveyed is calculated along the transect on a per segment basis to account for adjustments in transect width. These oscillations in vehicle position also profoundly influence the percentage of time that the ROV images capture the seabed thus affecting the survey yield.





As mentioned below there are considerations of improvements to the ROV system sensor package that would help improve and strengthen the estimates of total survey area. Transect width is indirectly estimated from analysis of the video imagery and the use of parallel laser pointers and an assumed flat floor. The addition of a high frequency forward looking multibeam echosounder for the ROV would provide some independent constraints on the seabed geometry. A forward looking multibeam sonar would also provide additional guidance and operational safety for ROV pilots in helping to navigate the complex terrains of these rocky hard-bottom reef areas. Absent the addition of a multibeam echosounder a separate single beam altimeter for use during the neadbed surveys would be helpful as it was noted that the existing downward altimeter is noisy and approaches blanking distance near the bed when it is most critically needed for the width estimation and for operational guidance.

An important realization with optical surveys be they video or still frames is that the imagery does not represent data in and of itself but always requires some level of annotation either by humans or through automated techniques. Another key component is that images represent a rich potential resource for analysis. There is a mantra within the NOAA mapping community to “Map once, Use Many Times”. This is a guiding principle driving many of the integrated seabed mapping efforts. This approach is also vitaly applicable and important for optical surveys. Photos that may have been gathered to provide ground truthing for multibeam echosounder surveys can provide a useful basis for assessing benthic habitat or providing images for fish stock assessment. Similarly, the very images collected by these ROV programs (ODFW and CDFW) which were designed for specific fish stocks could be examined for other aspects of benthic and near bed ecosystem assessment. The extent to which one can “photograph once, use many times” is dependent on the manner in which the photos and their associated metadata are derived and stored. Quite often, out of necessity, research groups scrape together metadata and conduct their own internal data storage and indexing which while it may work just fine for the local research team may limit the ability for these hard fought data to be made useful by others in the research community. Examples of these in house bespoke approaches include the Microsoft Access database referred to in both the ODFW and CDFW reports. Consideration should be made for integration and transfer of local databases into FGDC compliant datasets. Of particular value moving forward is to arrange data and image structures so as to make them readily available to use and be used by image toolkits. A great example of this is the NOAA Fisheries Strategic Initiative on Automated Image Analysis program. https://marineresearchpartners.com/nmfs_aiasi/Home.html

A major recommendation for both of these programs is to review and closely align the data collection, archiving, and image analysis to the tools and protocols outlined by the AIASI initiative. A benefit to the larger community image analysis efforts would come from thus having access to the derived imagery from the ROV surveys to use for further development and testing particularly of automated machine learning algorithms for fish detection and sizing.

Reports mention quality control processes and R scripts for data reduction and entry. These workflows and code bases should be made available for the follow on review and shared with the broader AIASI community.

ToR 3) **Evaluate proposed methods to develop indices or estimates of abundance from these ROV surveys, including using habitat/substrate type and Marine Protected Area designation as covariates.**

a. Are methods scientifically sound and robust?

b. Are the methods appropriate for the available data?

c. Are indices or estimates of abundance consistent with input data and population biological characteristics?

d. Recommendations/suggestions for improvement to methods.

Review of Tor 3

The methods for generating abundance estimates followed fairly standard set of approaches used in other optical surveys and to the credit and benefit of the program utilized multiple different techniques to generate independent estimates for generating substrate-specific densities. The programs are making excellent use of the existing multibeam sonar derived habitat maps to guide the stratified random sampling design of the ROV surveys and these maps are also utilized to generate substrate transitions for segmentation of the transects. While one of the express goals is to extend the abundance estimates beyond the surveyed areas to create a series of coastwide abundance estimates, caution is urged in this regard particularly with regards to extrapolation of abundances derived from Marine Protected Areas out into unprotected areas. Also, depth distributions and oceanographic conditions may not remain coherent over the coastwide domain and thus violate assumptions that would render such wide area indices erroneous.

With regards to the segment-scale data assessment there are as noted in the ODFW report, undesirable trade offs between segments that are too long (reduced sample size and loss of spatial variability) and segments that are too short (positioning errors produce large errors in density calculations). Obviously most of the post-processing data reduction choices are driven by time and personnel limitations. Machine Vision techniques could be incorporated to help address these issues. Small overlapping segments could be analyzed in a sliding box manner that would help address edge effects and noise associated with small segments while helping to aggregate over the full transect.

The methods outlined for generating substrate-specific densities are reasonable and make sense. ODFW outlined two methods- one that calculated a single weighted mean density for each substrate over all sites in the region and the other that calculates site specific densities and then summed all sites for a total abundance over the entire area. The latter has the benefit of preserving some site specific information that is useful for assessing changes through time and documenting variability within similar substrate sites.

The use of Generalized Additive Models (GAMs) as an approach and framework for modeling overall abundance is a reasonable and widely accepted approach. Cross-validation is particularly important for GAMs model development and also care must be taken in the interpretation of results for ranges of certain parameters that exceed most of the sampling, for instance estimates in depth ranges that are not frequently sampled. It is important and extremely useful to have a modeling framework in mind that is understood and anticipated by the field data collection otherwise there is greater potential that important variables will go unrecorded. The GAM models will improve as data sets expand both for available multibeam data and for ROV observation of fish abundance and size.

ToR 4) **Evaluate proposed methods to estimate size compositions of observed individuals of each species.**

a. Are methods scientifically sound, robust, and consistent with accepted practices?

b. Are the methods appropriate for the available data?

c. Are estimated size compositions consistent with input data and population biological characteristics?

d. Recommendations/suggestions for improvement to methods.

Review of ToR 4

Size composition estimates are in many ways more difficult to come by than abundance estimates. Abundance simply requires a positive identification of presence or absence. Size estimation requires the ability to measure a moving organism from a moving platform. Compared to size estimates of sessile benthic organisms measuring fish size is particularly challenging and leads to a greater rejection of data and thus estimates rely on even more sparse data sets than abundance. Sizing from a single fixed lens requires that the fish present itself laterally to the camera near the parallel lasers within a discernible background, a set of requirements that is not often met.

A general recommendation is for inclusion of stereo camera for length measurements. The recent addition of a GoPro stereo camera system to the ODFW ROV is mentioned but that system has not been fully integrated into the workflow though it is expected to be deployed on future surveys. Care should be taken to conduct lab and field verification of the stereo camera system. This can be done with the use of caught or frozen fish of measured size to establish the precision and accuracy of the stereo camera set up. Furthermore, it is important for stereo and single lens camera systems that metadata be incorporated that is preferably embedded within the images themselves. Metadata should include time, position, depth, altitude and any additional environmental and camera specific parameters in order to make the images useful for subsequent analysis.

ToR 5) **Identify potential impediments to developing independent indices or estimates of abundance using these ROV surveys and incorporating them into stock assessments.**

a. Are the results informative, robust and could they be incorporated into stock assessments?

b. Are there limitations to the use and incorporation of the indices or estimates of abundance into stock assessments?

Review of ToR 5

According to the ODFW report the abundance estimation was constrained to depths between 20-70 m. A potential impediment to the program findings might come from the limits of these depth ranges. It would be important to confirm that these depths cover the critical depths of the habitats of interest. Furthermore through a hypsographic analysis of the underlying regional multibeam bathymetry habitat map it would be possible to characterize the distribution of depths within the surveyed areas and make sure that the sampling distribution adequately captures this same distribution. This may already be the case but it was not directly evident from the material in the report.

A potential impediment to the strength of the inferences that can be drawn from the ROV surveys stems from the challenges involved in establishing sufficiently large numbers of samples- conducting transect surveys requires extensive commitments of time and funding. The biggest thing that would benefit the program is an increase in the temporal and spatial coverage. One option to explore through analysis of existing datasets is to determine if the 500 m transect length is large enough or if it can be reduced. If a satisfactory count outcome can be achieved with a shorter transect that may allow for an increase in the number of transect dive sites (referred to as site or location in the OR report).

ToR 6) **Provide guidance on key improvements in survey design or modeling approaches for future considerations.**

a. Consider research recommendations provided and make any additional recommendations or prioritizations warranted.

b. Provide recommendations on research and monitoring that could improve the reliability of, and information provided by, future visual surveys for assessments of nearshore stocks.

Review of ToR 6

As mentioned previously, the overall survey design is deemed to be sound and generally employs approaches used in other optical surveys of fishery stocks. There are some areas were further analysis and survey design improvements can be made. Assessing the transect length is one example of a topic that can be further studied. Improvements can and should also be made with regard to tracking errors and vehicle handling. The derived value of an ROV based optical survey program is strongly influenced by a high yield of quality imagery data and this requires careful and precise positioning of the vehicle. Positioning should be reported with RMS uncertainties in both horizontal and vertical positioning and summarized in each survey dive. In the 2013 ODFW survey there is mention of positional accuracy of +/- 4 m and also of "substantial ROV tracking errors" and it would be useful and informative to pursue the source and nature of those tracking issues more fully. The ROV system positioning from both the ODFW and CDFW programs could also be improved through the addition of a DVL aided IMU system to provide positioning and attitude measurements independent of the USBL acoustic tracking system. Another positioning approach could be executed utilizing visual odometry of the ROV from a downward facing camera during periods of visual lock of the seabed. This approach is utilized in other ROV and AUV systems but does require the investment of time and resources to customize and conduct the post-processing. It is clear from the ODFW report that already a considerable about of post-process smoothing is involved in the track line data estimates and these add uncertainties that propagate into the density calculations therefore efforts to improve the navigation will introduce a valuable fundamental improvement to the program. Additional characterization of the vehicle dynamics are important to capture and report- quantities such as roll, pitch, yaw, and depth/altitude dynamics such be reported and efforts made to reduce the uncertainties and variabilities in these parameters. Approaches could include having a few set transect lines that are run repeatedly in areas with high resolution baseline mapping and using these as an instrument verification dive akin to patch tests run during multibeam surveys.

Even in the absence of new technology platforms such as the AUVs mentioned below there are additional improvements that can be made with the existing ROV platforms. Stereo camera systems should be made standard on all of the ROVs and the images should be archived to include the needed metadata about positioning and vehicle attitude. Additionally it would benefit the program to incorporate multibeam and/or side-scan sonar into the ROV systems. Collecting side-scan sonar data at the same time as the camera operations would provide added value to the optical surveys. These data would be useful in navigation and positioning errors as the side-scan or multibeam could be readily compared against the existing background data. Furthermore these data themselves could be processed to examine fish abundances given the wider swath that sonar covers relative to optical systems. And finally, gathering additional sonar data will provide the basis for temporal monitoring and analysis of the underlying habitat map to account for changes.

ToR 7) **Provide a brief description on other aspects of the survey design or model estimation not described above.**

Review of ToR 7

Something not covered in the previous ToRs is for the consideration of other complementary technology approaches that could benefit the programs. With the goal of increasing the number of sites and surveys in order to achieve the needed outcome of increased fish counts and more repeated monitoring there are a number of technologies that could be included in the survey program. One example of this would be the incorporation of AUVs as a camera platform. In this class would be included both propeller driven AUVs and buoyancy engine gliders outfitted with color camera systems. The former would be capable of very precise and repeatable surveys of the seabed and being decoupled from the surface without a tether would increase the platform stability and yield a higher return of seabed images with less vertical variability and thus more consistent track width. In the case of the latter, a glider while not as spatially accurate and more susceptible to drift would, nevertheless, be able to conduct surveys over longer durations and through conditions that boat based operations could not operate. According to the ODFW report the abundance estimation was constrained to depths between 20-70 m and this is a depth range easily achievable by AUV systems. AUVs have the ability to conduct terrain following flight behavior which results in a very consistent offset and thus more constant image width over the seabed. In our studies of sea scallops even in rough hardbottom terrains associated with Georges Bank we see altitude values that are within +/- 10 cm of the commanded altitude. The major source of data loss within the ROV surveys comes from the “gaps” associated with bottom view loss. An AUV system would be an approach that would be helpful in closing those gaps.

Another technology that could be particularly useful for fish abundance counts would be a 360 degree camera or a set of fixed cameras pointing in each direction. 360 cameras are available with underwater housings and they capture still frame or video of a full spherical region. This would require additional post processing but would help capture cryptic species that may be actively avoiding the front end of the ROV as it transects through the environment.

Conclusions and Overall Recommendations

Overall the platform choices and configurations are considered to be sound and represent established ROV based technologies. Similarly, statistical treatments and approaches to expansion of the species level data into habitat based, MPA, and regional summaries employs robust approach incorporating a range of methods from simple aggregation to Generalized additive models (GAMs). In both survey programs that were examined (OR and CA) the operation teams have demonstrated a high quality of resulting scientific data

Sampling bias associated with any survey gear can result from many factors, including noise, light, motion and pressure waves generated by the gear. Such biases should be considered for any and all gear used in the stock and habitat surveys. Gear disturbance can result in avoidance by some mobile species, leading to underestimates in density, or in the attraction of other species, resulting in an overestimation of densities. It should be stressed that the more we can make the underwater vehicles “fish like”, or stealthier, the closer we will be to accurately reflecting the relationships that exist between marine animals and their habitats. The need for studies of bias underline the necessity of creating calibration sites that could be surveyed by all gear types.

Machine vision refers to the capability of extracting information from digital images through the use of algorithms- either through traditional image manipulation techniques or artificial intelligence “Deep Learning” neural network strategies. The hope is that machine vision will be used to more efficiently collect accurate data on the detection, quantification, and measurement of organisms and the classification of species and seafloor substrata. While the basic quality of the image is a function of platform and image processing, it should be noted that machine vision can be challenged by the complexity of the habitat and the diversity of organisms. A major challenge with machine vision detection systems is the need for large annotated image datasets for training and testing of the algorithms and the intensive work needed by trained human annotators to build such datasets.

Data management is an important consideration and one of the main areas of recommended further development. A major challenge presented by ROV systems is the massive quantity of data generated from image-based surveys. Data management is a major bottleneck in the field of underwater imagery throughout the marine science community, but by teaming up with experts in informatics and artificial intelligence such bottlenecks can be addressed. Automation of the identification of animals and habitats is part of the solution, and can be a useful tool, depending on the level of taxonomic and/or physical identification required. There are also open source software annotation systems available (for example: labelme from MIT or labelbox, or labelimage) that will help standardize data management and retrieval but a single standardized workflow may not satisfy all needs. An important consideration is the need for comprehensive metadata as well as the archiving of raw data as part of any management system, so that realistic comparisons can be made over time within a survey program and for comparison to other programs. Relational database structures are recommended and the use of secure and backed up servers that can be made available to other users in the field.

One of the issues for all of the programs is the cost of developing and operating undersea imaging equipment. As seen in the reports, these systems vary from ROVs to triggered cameras to trawls and their costs can vary tremendously requiring broad budgetary support both for acquisition and upkeep and maintenance. With the decommissioning of the submersible, DELTA, there is a need for making underwater survey equipment more available, and more frequently utilized as ROV surveys are often limited spatially and temporally. Regional programs should meet periodically to compare and share strategies and practices.

The case has been made that there is a growing need for monitoring change in underwater environments as use of the ocean and its resources increases. Baseline data to measure environmental change, over all habitats and spatial and temporal scales of impact, is generally lacking. Generating needed baseline data is a strong justification for moving forward with developing undersea imaging technology. In addition, our understanding of fundamental ecosystem processes and interactions occurring on the seafloor is rudimentary (particularly with increasing depth). Therefore, the development and expanded use of undersea imaging technology for basic fisheries research is important to monitoring change.

Appendix 1: Bibliography of materials provided for review

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- Marion, S., 2019. Abundance Estimation for Nearshore Groundfish from ROV Video Surveys of Oregon's Nearshore Rocky Reefs. Oregon Department of Fish and Wildlife Marine Resources Program Newport, Oregon. May 20, 2019 Draft report for Pacific Fishery Management Council, Science and Statistical Committee
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https://www.fisheries.noaa.gov/resource/data/2016-assessment-demersal-shelf-rockfish-stock-complex-southeast-outside-district-gulf

- The Pacific Fishery Management Council's Scientific and Statistical Committee's Terms of Reference for the Methodology Review Process for Groundfish and Coastal Pelagic Species for 2019-2020

Additional References

The following literature while not provided directly to the reviewer has relevance and is provided as a reference to the program participants.

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Appendix 2: A copy of the CIE Performance Work Statement

Performance Work Statement (PWS)

National Oceanic and Atmospheric Administration (NOAA)

National Marine Fisheries Service (NMFS)

Center for Independent Experts (CIE) Program

External Independent Peer Review

Remotely Operated Vehicle (ROV) Surveys of Nearshore Stocks - California & Oregon

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. (http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf).

Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

The National Marine Fisheries Service and the Pacific Fishery Management Council is seeking a desk review to evaluate and review fishery independent visual survey methodologies, using remotely operated vehicles, for nearshore Groundfish species off the states of Oregon and California.

West coast nearshore groundfish stock assessments have identified the current lack of fishery-independent data sources as a research and data need (PFMC, 2017,Agenda Item E.2, Attachment 1, September 2017). In addition, methods currently utilized in stock assessments do not explicitly account for differential biomass densities inside of no-take Marine Protected Areas (MPAs). Remotely operated vehicles (ROVs) provide a non-lethal sampling method in areas where harvest is prohibited. They also allow collection of data on overfished species and nearshore species that constrain take of healthy stocks. Because ROVs employ only non-lethal data collection methods, they avoid the need for research catch set-asides or other allocative considerations that may arise between fisheries and research sectors.

Both Oregon and California have conducted ROV surveys of rockfish in nearshore areas, focusing on rocky reef habitat, and, in California, on areas inside and outside of MPAs. In both states, resultant information includes density estimates (by transect and habitat) for various species and length data. In addition, the states have developed seafloor maps, allowing estimation of area of habitat types by depth and latitudinal breaks.

Density estimates can be developed in a number of ways, from simple extrapolations to more complex general linear models (GLMs) and generalized additive models (GAMs), including factors that may affect detection probability across sample sites. There is likely to be differential detection by species, gender and size, and by timing of survey as well.

Observed density estimates and indices of relative abundance or estimates of absolute abundance in the depth and latitudinal areas surveyed can be used in stock assessments, given appropriate accounting for selectivity and detection probability, or potentially used in management procedures. Length composition data collected by the surveys may be included in stock assessments or management procedures as well.

The general goals and objectives of Council methodology reviews are to:

1) Ensure that research surveys, data collection, data analyses and other scientific techniques in support of coastal pelagic species (CPS) and groundfish stock assessments are the best available scientific information and facilitate the use of information by the Council;

2) Provide recommendations regarding whether, and if so, how a particular methodology can be applied in future stock assessments;

3) Meet the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (MSRA) and other legal requirements;

4) Follow a detailed calendar and fulfil explicit responsibilities for all participants to produce required outcomes and reports;

5) Provide an independent external review of survey and analytical methods used to develop data to inform CPS and groundfish stock assessments;

6) Increase understanding and acceptance of CPS and groundfish research methodologies and review by all members of the Council family;

7) Ensure that methodologies not directly related to stock assessments, such as economic analyses or ecosystem-based fishery management approaches, undergo adequate peer review, as appropriate; and

8) Identify research needed to improve assessments, reviews, surveys, analyses, and fishery management in the future.

The goals and objectives specific to the review of the California and Oregon ROV survey methodologies are to:

1) Evaluate the sampling design used in recent ROV surveys conducted by the states of Oregon and California.

2) Evaluate proposed methods to develop indices or estimates of abundance for these ROV surveys, including using habitat/substrate type and Marine Protected Area designation as covariates.

3) Evaluate proposed methods to estimate size compositions of observed individuals of each species.

4) Identify potential impediments to developing independent indices or estimates of abundance using these ROV surveys and incorporating them into stock assessments.

This methodology review will likely provide feedback on the initial development of materials and guidance for future ROV surveys and the development of indices or estimates of abundance for those areas surveyed in Oregon and California, as well as the expansion of such methods to other areas within those states and/or within Washington State. The desk review of these survey methodologies will be followed-up with an in-person panel review tentatively scheduled for early-December 2019.

The specified format and contents of the individual peer review reports are found in **Annex 1**. The Terms of Reference (ToRs) for the review of ROV survey methodologies are listed in **Annex 2**.

Requirements

NMFS requires two (2) reviewers to conduct an impartial and independent peer review in accordance with the PWS, OMB guidelines, and the ToRs below. The reviewers shall have a working knowledge in visual survey techniques, survey design and analysis, and familiarity with incorporating survey information in stock assessments. Additionally, these CIE reviewers will participate in a follow-on panel review to be held in early December 2019 (See **Attachment A**).

Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

Tasks for Reviewers

1) Review the following background materials and reports prior to the review:

Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact(s) in advance of the peer review, including detailed reports of previously conducted and proposed ROV surveys and analysis methods from each of the states of Oregon and California. Two weeks before the desk review, the NMFS Project Contact(s) will send (by electronic mail or make available at an FTP site) to the CIE reviewer the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact(s) will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to them in accordance to the PWS scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Documents to be provided to the CIE reviewers prior to the methodology review include:

- Reports by the states of California and Oregon describing survey and analysis approaches and preliminary results;

- The Pacific Fishery Management Council's Scientific and Statistical Committee's Terms of Reference for the Methodology Review Process for Groundfish and Coastal Pelagic Species for 2019-2020;
- Additional supporting documents as available.
- An electronic copy of the data, the parameters, and the software used for developing population indices/estimates and compositional data.

3) Desk Review: Each CIE reviewer shall conduct the independent peer review in accordance with the PWS and ToRs, and shall not serve in any other role unless specified herein. Modifications to the PWS and ToRs can not be made during the peer review, and any PWS or ToRs modifications prior to the peer review shall be approved by the NMFS Project Contact.

4) Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the PWS. Each CIE reviewer shall complete the independent peer review according to required format and content as described in **Annex 1**. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in **Annexes 2 and 3**.

5) Deliver their reports to the Government according to the specified milestones dates.

Place of Performance

Each CIE reviewer shall conduct an independent peer review as a desk review, therefore no travel is required.

Period of Performance

The period of performance shall be from the time of award through July 2019. Each reviewer's duties shall not exceed 10 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
No later than two weeks prior to the review	Contractor provides the pre-review documents to the reviewers
May 2019	Each reviewer conducts an independent peer review as a desk review
Within two weeks after review	Contractor receives draft reports
Within two weeks of receiving draft reports	Contractor submits final reports to the Government

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards:

(1) The reports shall be completed in accordance with the required formatting and content; (2) The reports shall address each ToR as specified; and (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

Since this is a desk review travel is neither required nor authorized for this contract.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

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Annex 1: Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether or not the science reviewed is the best scientific information available.
1. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.
1. The reviewer report shall include the following appendices:
    1. Appendix 1: Bibliography of materials provided for review
    2. Appendix 2: A copy of the CIE Performance Work Statement

Annex 2: Terms of Reference for the proponents of ROV methodologies

Remotely Operated Vehicle (ROV) Surveys of Nearshore Stocks - California & Oregon

The specific responsibilities of each of the proponents are to:

1) Prepare a Peer Review Report that summarizes the Reviewer's evaluation of the California and Oregon ROV surveys of nearshore stocks following the Terms of Reference.

2) Evaluate the sampling design used in recent ROV surveys conducted by the states of Oregon and California, addressing the following:

a. Are sampling designs appropriate

i. To develop estimates or indices of abundance by species in the surveyed areas

ii. To estimate size composition by species

iii. To expand these to areas outside of the those surveyed

iv. for use in assessment models as indices of abundance or otherwise, or for use in management procedures?

b. Recommendations/suggestions for improvements to sampling designs

3) Evaluate the video and data processing tools/methods and methods to determine total area surveyed for each transect.

a. Are methods scientifically sound and robust?

b. Are the methods appropriate for the available data?

c. Recommendations/suggestions for improvement to methods.

4) Evaluate proposed methods to develop indices or estimates of abundance from these ROV surveys, including using habitat/substrate type and Marine Protected Area designation as covariates.

a. Are methods scientifically sound and robust?

b. Are the methods appropriate for the available data?

c. Are indices or estimates of abundance consistent with input data and population biological characteristics?

d. Recommendations/suggestions for improvement to methods.

5) Evaluate proposed methods to estimate size compositions of observed individuals of each species.

a. Are methods scientifically sound, robust, and consistent with accepted practices?

b. Are the methods appropriate for the available data?

c. Are estimated size compositions consistent with input data and population biological characteristics?

d. Recommendations/suggestions for improvement to methods.

6) Identify potential impediments to developing independent indices or estimates of abundance using these ROV surveys and incorporating them into stock assessments.

a. Are the results informative, robust and could they be incorporated into stock assessments?

b. Are there limitations to the use and incorporation of the indices or estimates of abundance into stock assessments?

7) Provide guidance on key improvements in survey design or modeling approaches for future considerations.

a. Consider research recommendations provided and make any additional recommendations or prioritizations warranted.

b. Provide recommendations on research and monitoring that could improve the reliability of, and information provided by, future visual surveys for assessments of nearshore stocks.

8) Provide a brief description on other aspects of the survey design or model estimation not described above.