EXECUTIVE SUMMARY

Final Report of the Science Advisory Committee

Scientific and Technical Review of the Survey Design and Methods used by the California Department of Fish and Wildlife to estimate red abalone (*Haliotis rufescens*) density

Photo: Steve Lonhart

Authored by the
Science Advisory Committee

Coordinated by the
California Ocean Science Trust

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California Department of Fish and Wildlife

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Review Participants

California Ocean Science Trust

Ocean Science Trust is a nonprofit 501(c)(3) public benefit corporation established pursuant to the California Ocean Resources Stewardship Act of 2000. Ocean Science Trust's mission is to advance a constructive role for science in decision-making by promoting collaboration and mutual understanding among scientists, citizens, managers, and policymakers working toward sustained, healthy, and productive coastal and ocean ecosystems.

Ocean Science Trust served as the independent appointing agency in alignment with the Procedural Guidelines for CDFW Ad Hoc Independent Scientific Advisory Committees[1]. Ocean Science Trust convened the Science Advisory Committee (SAC), and designed and implemented a scientific review process (see Appendix C) that promoted objectivity, transparency, and scientific rigor.

Science Advisory Committee (SAC)

Mark H. Carr (Chair)

Professor, Department of Ecology and Evolutionary Biology, University of California, Santa Cruz

Dr. Mark Carr is a populations and community ecologist and has extensive experience conducting SCUBA-based research on the ecology of coastal marine fishes, invertebrates, and kelp forest ecosystems in southern and central California.

Karina J. Nielsen

Professor, Department of Biology, Sonoma State University

Dr. Karina Nielsen is a marine ecologist with over two decades of hands-on experience designing and conducting field experiments and surveys of invertebrates and other marine organisms on rocky shores, sandy beaches, and salt marshes.

Jeremy Prince

Adjunct Associate Professor, Murdoch University, Perth, Western Australia; Biospherics, South Fremantle, Western Australia

Dr. Jeremy Prince is a resource assessment modeler working at the interface between government and the fishing industry. He has worked widely developing survey and assessment methodology for species as divergent as deepwater fish, sharks, dugong, sea urchins, rock lobster, and abalone.

Peter Raimondi

Chair/Professor, Department of Ecology and Evolutionary Biology, University of California, Santa Cruz

Dr. Raimondi is interested in understanding factors that are important in the development and maintenance of biological communities. He uses experimentation and field observations of populations and community structure and distributions to motivate testable hypotheses concerning mechanisms affecting development and maintenance.

[1]Available at: https://nrm.dfg.ca.gov/documents/ContextDocs.aspx%3Fcat%3DScienceInstitute

Stephen C. Schroeter

Research Ecologist, Marine Science Institute, University of California, Santa Barbara, Adjunct Professor, Department of Biology, San Diego State University

Dr. Schroeter is a population and community ecologist working in a variety of habitats including rocky intertidal and subtidal reefs, tidal wetlands, and coastal sage scrub and coastal chaparral communities. This work has involved designing and implementing robust sampling designs aimed at assessing the performance of kelp forest algae, invertebrates, and fish on a large artificial reef and natural reference reefs in San Diego county.

Brian Tissot

Director/Professor, Marine Laboratory, Department of Biology, Humboldt State University

Dr. Tissot is a marine ecologist with over three decades of experience conducting research on invertebrates and fishes in intertidal zone, kelp forest, coral reef, and deep-sea ecosystems. As part of his PhD dissertation he tagged over 5,000 black abalone on Santa Cruz Island and Año Nuevo Island, California and followed them for over 15 years.

California Department of Fish and Wildlife Science Team

California Department of Fish and Wildlife scientists most familiar with the design, methodology and application of red abalone density surveys were engaged in the process and provided input and feedback as necessary throughout the review process. CDFW Marine Region Program Manager, Tom Barnes, was the primary management contact for this review process.

Laura Rogers-Bennett, Senior Environmental Scientist, California Department of Fish and Wildlife, Research Associate, University of California, Davis

Cynthia A. Catton, Environmental Scientist, Invertebrate Project, Marine Region, California Department of Fish and Wildlife

Ian Kei Taniguchi, Senior Environmental Scientist, California Department of Fish and Wildlife

Executive Summary

This Final Report of the Science Advisory Committee was prepared in response to a scientific and technical review request by the California Department of Fish and Wildlife (CDFW). CDFW's goal in asking for this review was to determine the most robust and tractable methods for estimating red abalone density, which informs management of the northern California recreational fishery. Ocean Science Trust, an independent non-profit dedicated to advancing a constructive role for science in decision-making, designed and facilitated all aspects of the review in alignment with the CDFW Science Institute Procedural Guidelines for Ad Hoc Independent Scientific Advisory Committees.

Maintaining Credibility and Transparency in the Review Process

Upon garnering recommendations from CDFW, the scientific community, and key abalone stakeholder groups, Ocean Science Trust worked with the Ocean Protection Council Science Advisory Team to identify and convene a Science Advisory Committee (SAC) composed of six external experts from appropriate disciplines. The review process took place between July 2013 and June 2014 and was comprised of several public webinars as well as a one-day technical workshop involving the SAC and CDFW scientists. The conversations that occurred between the SAC, CDFW biologists, and stakeholders at each of these key process points, as well as additional analyses conducted by the SAC on CDFW abalone density data formed the basis for this report.

Key Recommendations to Strengthen Current Analytical Methods

The SAC's main evaluation and recommendations aim to strengthen the current sampling and analytical methods under the existing guidelines of the ARMP, and are not intended as an endorsement of the methods that are effectively set by the ARMP. The SAC's recommended analyses center on addressing the primary management question: Given the survey data, what is the likelihood that the actual population has crossed the triggers specified in the ARMP?

Recommendation: Calculate and Plot Estimates of the Population Mean and their associated Confidence Intervals through Time

The sub-samples of abalone captured by the dive surveys are used to estimate the true abalone population density at a given site. What is uncertain is the accuracy of the estimated density, and thus whether or not abalone populations have declined or increased to the point necessitating management action. The density survey data are highly variable due to unavoidable differences in transect location and quality of abalone habitat, as well as year to year and site to site differences in the number of abalone. An important first step to assessing population density estimates relative to management triggers is to consider this variability in abalone density estimates among transects. A very useful analysis for exploring trends over time relative to management triggers, and the uncertainty of those estimates, is to calculate and plot the mean abalone density for each spatial and temporal sampling unit (i.e., a site or the four

index sites within a county for a particular sampling period), and their associated confidence intervals (CI). This approach will allow CDFW, the FGC, and others to see how density is changing over time, revealing population trajectories.

To use CIs, the FGC should make an a priori decision about what level of confidence they require of these density estimates to decide that no management action is necessary. For instance, if the FGC decides that they require 95% confidence that they have not crossed a trigger value, then they should examine figures with that confidence interval plotted, along with the relevant management trigger. In the event that the FGC specified confidence interval encompasses the trigger value, regardless of the mean value, then the possibility that the management trigger has been met or surpassed cannot be excluded and there is risk associated with the failure to act.

Recommendation: Generate Cumulative Probability Functions

As a next step, the SAC recommends generating Cumulative Probability Functions (CPF) as the analytical method allowing managers and interested stakeholders to transparently discuss the likelihood or risk that populations have crossed specified management triggers, given the population density estimate and its uncertainty. While CIs help provide an assessment of whether population densities have changed over time, and whether or not they are clearly above or below a trigger level, CPFs provide a means to explicitly evaluate the likelihood that the actual population density has met or surpassed a trigger level.

The CPF is set by the mean, the target value of interest (such as the management trigger), and the standard error of the mean, a measure of variability of the data used to estimate the mean, that takes into account the number of samples that estimate is based on. Considering management options at the different spatial scales (i.e., site, county, fishery) requires separate CFP's for each spatial scale of interest. CPFs can be calculated for any management trigger, such as the depth refuge trigger.

CPFs provide a powerful tool in that they should be compared against target confidence levels set by the FGC a priori. In other words, CPFs can help the FGC think about the tradeoff between the risk of saying the population has not crossed the threshold when it really has, verses the risk of saying the population has crossed the threshold when it has not. Risk being defined as the risk to population and fishery viability, as well as to curtailing a recreational and fishery opportunity for the general public.

Additionally, CPF provides a relatively simple way to assess the adequacy of a sampling design for given management goals. CPF modeling exercises can help to explore tradeoffs between the number of sites and number of samples (i.e. transects) at each site. For example, increasing the number of sites surveyed can increase the "steepness" of a CPF curve (i.e. extent to which confidence changes with change in the estimated mean), or one's confidence that a given measured density value is above or below a trigger.

Ultimately, considering the raw data, the confidence limits, and the probability that the abalone population density has reached the trigger where some management action is required will provide the FGC with the best guidance as they consider management actions.

Additional Considerations to Potentially Improve Survey Methods and Analyses

The SAC also discussed some general limitations and potential improvements to the current survey methods. These items should be considered in future discussions as CDFW and the FGC move towards long-term management of red abalone.

- **The survey design employed by CDFW requires approximately three years to survey every site.** Given the potential for rapid changes in the abundance of these populations, and the shifting patterns of fishing effort, the current frequency of sampling is probably not adequate for management to detect and respond to rapid changes in population status.
- **This sampling method was not designed to represent or estimate the density of the entire abalone population, or to determine stock-wide biomass.** If the goal of management is to track the condition of abalone populations throughout their range (i.e., stock size, size structure, recruitment rates), a different survey design should be considered and additional survey sites should be included.
- **This review did not evaluate the population size structure data used to evaluate the recruitment trigger in the ARMP.** Size structure data could be used to develop a population viability model and risk assessment, which would provide an additional, independent method of assessing the health of the red abalone fishery. This needs to be explored.
- **Magnitude and distribution of statistical error (variability associated with an estimate of mean density) will vary based on whether the data analyzed incorporates all eight sites (fishery level), four sites (county level), or one (site level).** At the site level the existing variance structure of the underlying transect-level data exhibit substantial deviations from the assumptions of normality and homogeneity of variance that are required by standard parametric statistical analyses. Other non-parametric statistical techniques need to be employed (e.g., Monte Carlo resampling) to analyze transect data at the level of the individual site.
- **Analysis of variance (ANOVA) is not the most appropriate method for addressing the fixed management thresholds specified in the ARMP.** The ANOVA approach used by CDFW does not answer the question of whether abalone densities are above or below specific management triggers.
- **Analysis of Variance (ANOVA) that uses transects as replicate estimates of mean density does not provide inference about abalone populations outside of the eight fished index sites.** Assuming that these eight sites are representative of the north coast, treating transects as independent replicates, commits a statistical error known as pseudoreplication because it is expected that transects within a single site will be more similar to each other than to those from other sites. More importantly, the reality is these are not independent samples taken from a region. They are transects are nested within sites, thus it is very likely that they are non-independent. To make inferences about abalone populations across the entire North Coast, CDFW would have to modify both the survey design and data analysis.
- **The power analyses generated by CDFW is only applicable to the populations of abalone within the eight index sites.** This power analysis is subject to all the same

caveats as the ANOVA and overstates the power to detect changes across the entire region.

- **Statistical modeling techniques can help reduce the uncertainty associated with density estimates.** It is worth exploring whether statistical modeling techniques can help reduce the uncertainty associated with the density surveys. For instance, General Linear Models (GLMs) that incorporate data from all surveys years and sites, can provide powerful and practical ways to increase the precision of estimated densities without requiring additional physical surveys.
- **Additional data, such as habitat type, depth, and recruitment data can provide contextual information to help understand changes in density.** CDFW collects a great deal of valuable data in addition to density, including habitat attributes, depth, and recruitment. This information could be used to understand the context – or the "why" – density may or may not be changing.

Advancing Science to Better Inform Future Management

With CDFW's commitment to revise the ARMP and/or create a separate Fisheries Management Plan (FMP) for the recreational red abalone fishery, there is now an opportunity to build on the existing density data set to redesign the best possible sampling protocol for the species. Throughout the course of their discussions, the SAC identified a number of potential improvements to the assessment of abalone populations that go beyond the statistical and sampling questions that were at the center of the review scope. These suggestions may be helpful to consider in the future process to revise the ARMP or build an FMP.

Recommendations Associated with Existing Density Metric

- **Additional, robust collaboration with outside scientific experts will enhance the intellectual resources contributing to sampling and analysis of red abalone populations.** There are ample opportunities for CDFW to take advantage of the substantial intellectual resources within (and outside) the state to improve understanding of abalone populations. The SAC recommends establishing a standing review committee for the ARMP, somewhat analogous to the Statistical Committee of the federal Pacific Fisheries Management Council, to provide recommendations on the sampling design, analyses and interpretations conducted and generated by this program.
- **Make abalone survey data publicly available.** This would allow outside experts to verify and improve upon the analytical methods that are used for management of this important fishery, as well as help increase perceptions of credibility and build capacity without draining CDFW resources.
- **Consider alternatives to the use of eight index sites to manage the entire fishery.** A sampling protocol distributed across the region would provide a better picture of the stock as a whole, rather than solely within the eight index sites.
- **Develop strategies for more rapid tracking of the resource.** In any new survey design, a highly desirable trait would be the ability to gain data at every site on an annual basis.
- **Incorporate an understanding of the variability of the habitat.** Because certain habitat types are more suitable for abalone than others, incorporating understanding of the habitat (e.g., distribution and quality) at a site can help interpret density estimates. The recently generated seafloor maps for the state of California should be considered for this purpose.

More broadly, CDFW should ensure that their random transect approach accurately captures the distribution of habitat types at the sites.

- **Codify appropriate analysis in the ARMP.** While the ARMP sets very specific guidelines for surveying density and triggers for management action, it is silent on the appropriate level of confidence required in the density estimates to require management action.
- **Revisit sustainable fishery density: incorporate additional data or establish a baseline with greater biological significance.** Given that there were no differences noted between the baseline surveys and the later survey period in 2003, it would be appropriate to consider new baseline numbers from a time period when every index site was surveyed.
- **Modify the current density survey design for a more powerful and efficient approach, including:**
    - **Consider abandoning the sampling of deep transects.** The deepest depth strata where very few individuals reside will skew (zero-inflating, i.e., many counts of zero individuals) the resulting data in ways that impair statistical analyses. However, there are important implications for the inferences generated from any altered sampling designs, which also need to be considered.
    - **Use of permanent or fixed transects.** This approach has the potential to record changes in specific locations and move to the level of monitoring an index of abalone populations rather than managing around an arbitrary density using random transects. Permanent transects do not confound measures of temporal change in density with differences caused by sampling different locations each sampling event. However, they can also involve greater logistical costs.
- **Further explore the utility of fishery-dependent catch data as a tool for informing management.** Our initial analysis of the total recreational take did not reveal a clear relationship between recreational take and density survey data. However, take data depends on effort and changes in regulations (bag limit, area closures), thus catch-per-unit-effort may be a more informative metric than total take.

Recommendations for Moving Beyond a Density Metric

- **Transition to tracking the state of the abalone population.** CDFW now has a valuable long-term data set that could potentially serve as the foundation for restructuring the monitoring and management triggers around whole population indicators.
- **Exploring alternative scientifically based management reference points.** Assuming there is a stock-recruitment relationship, a better metric in lieu of or in addition to density may be to use a fecundity index like Spawning Potential Ratio (SPR) adjusted by nearest neighbor distances.

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