Final Report of the Scientific and Technical Review Panel

Scientific review of the draft Fishery Management Plan for Pacific herring (*Clupea pallasii*)

Convened by the California Ocean Science Trust

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Review Participants

CALIFORNIA OCEAN SCIENCE TRUST

California Ocean Science Trust is a boundary organization. We work across traditional boundaries, bringing together governments, scientists, and citizens to build trust and understanding in ocean and coastal science. We are an independent non-profit organization established by the California Ocean Resources Stewardship Act (CORSA) of 2000 to support managers and policymakers on the U.S. West Coast with sound science, and empower participation in the decisions that are shaping the future of our oceans. For more information, visit our website at www.oceansciencetrust.org.

Ocean Science Trust served as the independent appointing agency in alignment with the Procedural Guidelines for the California Department of Fish and Wildlife's Ad Hoc Independent Scientific Advisory Committees. Ocean Science Trust convened the review panel and designed and implemented a scientific review process that promoted objectivity, transparency, and scientific rigor (see Appendix A).

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CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE

The mission of the Department of Fish and Wildlife is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public.

California Department of Fish and Wildlife staff were engaged throughout the review process. They delivered presentations to the review panel and supplied additional data, information, and feedback to Ocean Science Trust as necessary throughout the review process.

Ryan Bartling, Environmental Scientist, California Department of Fish and Wildlife, was the primary management contact for this review.

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Background

The San Francisco Bay Pacific herring (*Clupea pallasii*) population supports a valuable fishery for herring roe (kazunoko), and a smaller herring-eggs-on-kelp (komochi or kazunoko kombu) fishery. San Francisco Bay also supports a limited commercial fresh fish and recreational fishery. The California Department of Fish and Wildlife (CDFW) developed a draft fishery management plan (FMP) to guide commercial and recreational fisheries for Pacific herring to ensure sustainable fishing levels.

FMPs assemble information, analyses, and management options to guide the management of the fishery by CDFW and the Fish and Game Commission (Commission). The FMP becomes effective upon adoption by the Commission, following their public process for review and revision. Thus, it is important for the scientific underpinnings of the draft FMP to have undergone independent review prior to submission to the Commission. External, independent peer review of the scientific underpinnings of the draft FMP is one way to provide the Commission and stakeholders assurances that FMPs are based upon the best readily available scientific information, as set forth under the Marine Life Management Act (MLMA).

REVIEW SCOPE

Ocean Science Trust worked with CDFW to develop a scope of review focusing on the scientific and technical elements of the proposed management framework that will guide fishery management decisions for the San Francisco Bay Pacific herring stock in the Pacific herring draft FMP and supporting materials. Thus, the review is not intended to be a comprehensive assessment of the entire draft FMP or the proposed approach to management contained therein, but rather focuses on key components identified below. This review focussed on whether the available data and predictive model that underpin the proposed draft FMP management strategy are applied in a manner that is scientifically sound, reasonable, and appropriate. Therefore, the central question of this review was:

Given CDFW's available data streams and analysis techniques, are the applications of the analyses to the integrated management strategy scientifically sound, reasonable, and appropriate?

Specifically, the review focused on evaluation of the following components of the draft FMP:

1. The accuracy and representation of existing literature on the biology of the stock and in the essential fishery information

2. The proposed spawning stock biomass thresholds and associated harvest rates underpinning the catch quota decision making process and signaling when the fishery may warrant management response

3. The decision matrix of ecosystem indicators and the rationale behind the inclusion of these ecosystem indicators in management

4. The science underpinning additional conservation and management measures

5. Identification of research and methods needed to improve assessments and fishery management in the future

For clarity we note that the following are not included in the scope of the current review:

- The data collection protocol, as it has been reviewed previously.
- The new predictive SSB model for spawning stock biomass, as the model underwent separate peer review and was published (Sydeman et al., 2018).

SUMMARY OF THE REVIEW PROCESS

This review took place from February 2018 - October 2018. Ocean Science Trust implemented a scientific review process that sought to promote objectivity, transparency, candor, efficiency, and scientific rigor. Following a broad solicitation for potential reviewers, coordinated via the Ocean Protection Council Science Advisory Team, a multidisciplinary, four-member review panel was assembled, representing expertise in fisheries science and management, marine ecology, stock assessment, and modeling. Ocean Science Trust facilitated constructive interactions between reviewers and CDFW through a series of remote meetings, where CDFW staff provided reviewers with the management context, presented an overview of the science and technical elements under review, and were available to answer reviewers' questions. In addition, Ocean Science Trust convened reviewers independently to allow the review panel to candidly discuss the review materials and conduct their assessment. Ocean Science Trust worked with the review panel to assemble and synthesize their written and verbal responses to guiding questions, as well as discussion from remote meetings into this final report. This report is publicly available on the Ocean Science Trust website.

PROJECT MATERIALS UNDER REVIEW

The following materials were provided by CDFW to the review panel for scientific and technical review:

- Draft Pacific herring Fishery Management Plan, Chapters 2-8.
- Draft Pacific herring Fishery Management Plan Appendices, 200 pages.

Additional data and information were provided by CDFW at the request of the review panel to assist with their assessment throughout the review process.

Review and Recommendations

Foremost, the review panel acknowledges the impressive effort that went into developing the management strategy in the Pacific herring draft fishery management plan (FMP) by the California Department of Fish and Wildlife (CDFW), the Pacific herring Steering Committee, other stakeholders, and outside experts, including the Farallon Institute. The preparers of these documents have thoughtfully considered a diverse amount of information. CDFW produced a management approach for the San Francisco Bay Pacific herring stock that integrates economic, ecological, and population considerations in a simple, flexible, and precautionary framework. The commitment to sustainability is clear, with a focus on minimizing years of a depressed stock, maintenance of a healthy age structure, maintenance of an economically viable fishery, and ensuring Pacific herring remain an important component of the ecosystem. The review panel believes these goals are both appropriate and commendable.

There are, however, details and further considerations that may improve the overall draft FMP and future performance against objectives. Additional scientific guidance and considerations are included that would produce a more scientifically robust FMP, as well as longer-term recommendations, data, and research needs that would strengthen the science contained within the draft FMP and its ability to inform management as new information and analyses become available. These recommendations will be addressed in more detail in the following sections.

This assessment is structured around the key focal areas identified in the scope of review (page 4). These recommendations aim to improve the science supporting the proposed management framework and, where possible, provide insight on the implications of each recommendation.

In addition to the recommendations included in this assessment, reviewers also provided in-text comments to CDFW. These comments did not substantially change the content of the draft FMP, but supported the improvement of the FMP document. Any comment that required additional discussion was pulled out and included in this report. In-texts comments included:

- The addition of citations
- Suggested edits to language for clarity and comprehension

Below are the scientific review panel's recommendations. Recommendations are identified as those that CDFW should address prior to adopting the FMP, and those that are longer-term considerations, which could be addressed following adoption of the FMP.

1. ESSENTIAL FISHERY INFORMATION

In accordance with the Marine Life Management Act (MLMA) sustainability objectives, CDFW is required to collect and maintain the most up-to-date Essential Fishery Information (EFI). The EFI includes information about species biology and life history, habitat requirements, population dynamics, fishing effort, catch level, socio-economic value of the fishery, and other information that would permit the fishery to be managed sustainably. The draft FMP also outlines how to address missing or outdated EFI.

Overall, reviewers found the representation of the existing literature on the biology of the stock was accurate and considered much of the core and relevant information. However, the panel did have recommendations for where clarification would be helpful and additional information gaps could be filled. Section 1.1 contains key recommendations that would allow for greater clarity and a more robust approach and should be considered before adopting the FMP. Section 1.2 includes recommendations that could improve the management of the fishery but are not imminent priorities and/or may require longer-term investment and research.

1.1   Key recommendations

1.1.1   Fecundity

Mass-specific fecundity is a core component of calculating spawning biomass from egg deposition surveys. The current estimates of fecundity and the relationship with weight, as stated within the draft FMP, require further justification. Specifically, it is well known that fecundity per unit mass varies with mass and length, as well as environmental conditions in herring. As a result, applying a single mass specific conversion requires justification. For example, this may be as simple as providing evidence that mass-specific fecundity is reasonably close to consistent regardless of female body mass, and is relatively time-invariant. Moreover, the rationale for monitoring fecundity infrequently, and how that information is used to update estimates, requires discussion. Specifically, Chapter 3 notes that,

> "Direct fecundity measurements are resource intensive, and so the Department only measures fecundity periodically (approximately once a decade; R. Bartling, Personal Communication). Currently, the Department assumes a fecundity rate of 217eggs/g for females in San Francisco Bay, though a recent estimate suggests that fecundity may have declined during the warm water conditions between 2013 and 2016 (Table 3-5). The fecundity, along with the sex ratio of each observed spawning wave, is used to calculate the total weight of fish that must have laid the number of eggs observed in spawn surveys."

Collecting higher-resolution information on fecundity should be an important part of EFI and lack of this information should be discussed and justified beyond the fact that they are resource intensive. Moreover, what "approximately once a decade" means should also be described in either in text or in a table with actual information about sampling years, estimates, and plans for continuation of collection of these data. These recommendations are included as a priority, in part, because using outdated or poor estimates of fecundity can impose substantial bias on estimates of spawning biomass.

1.1.2   Spatial and temporal variation

More clarity on the spatial structure of the Pacific herring populations, including maps, graphics and detail to describe how and why populations vary over time is needed.

Additionally, it was not immediately clear in the current draft how spatial information included fit together to inform the management strategy. Questions around whether spatial samples of age structure and sex-ratio are weighted by biomass need to be addressed. If not, skewed sex ratios or age structure from small spot spawns may disproportionately affect overall estimates if they have similar sample sizes for these metrics. It would also be useful to consider if spatial distributions of biomass could be used to inform when and where fisheries occur.

Similar to spatial information, it is currently unclear how temporal information is aggregated to inform the management strategy. Specifically, spawning waves often vary in sex ratios, size-at-age, and age structure. The draft FMP should describe how this information is brought together and whether, during sampling, there is a concerted effort to capture this variation.

1.1.3   Rapid Spawn Assessment Method

The reviewers recognize the potential value of an efficient alternative to the current survey protocols for use in areas outside of San Francisco Bay. However, the current description of the Rapid Spawn Assessment Method lacks sufficient detail. Reviewers would like to see specifics about methods of data collection, data produced, their utility, and a summary of results/products thus far included in the draft FMP. To assess the validity of the method, CDFW should also provide any information on, or plans for, assessment of this approach when applied to data-rich San Francisco Bay. Specifically, are quantitative or qualitative trends comparable between the full spawning protocols and the Rapid Spawning Assessment Method in San Francisco Bay? It would also be useful to provide information on potential costs as compared to current data collection protocols. In sum, if this approach is to be included in the FMP, please provide sufficient detail to evaluate its efficacy and purpose; otherwise, it should be removed.

1.1.4   Monitoring of young-of-year (YOY)

The proposed statistical model used for forecasting spawning stock biomass relies on indices of abundance of YOY. These data are thus a core priority for managing this fishery. The FMP should therefore adequately address the importance of conducting these surveys annually and with sufficient investment to ensure data quality that matches or exceeds recent records used to calibrate the statistical models.

1.2   Longer-term recommendations

While CDFW has an abundance of EFI for the San Francisco Bay Pacific herring stock, they should consider additional data sources and/or research and monitoring in support of acquiring and maintaining the most up-to-date EFI to support a sustainable Pacific herring stock. These data may include higher resolution monitoring of female fecundity, spatial and temporal genetic structure, spatial variation in growth rates, habitat availability and suitability, maturity-at-age, and any information on range shifts within and around the San Francisco Bay. These data would be helpful to test whether assumptions made about the stock dynamics are accurate and to improve forecasts of stock biomass.

Specific longer-term considerations for essential fishery information are listed below:

1.2.1   Population structure

There is a new body of evidence from northern populations of Pacific herring that spawning aggregations separated by several weeks or more in timing exhibit genetic differentiation when using high resolution molecular markers (L. Hauser and E. Petrou, unpublished data). Given that spawn timing in San Francisco Bay spans months, CDFW may consider utilizing these new markers to evaluate if there is genetic structure by spawn timing or geography. These may help inform whether spatial or temporal considerations in management are necessary.

In addition, given this is the southern end of their range, there is a high potential for range shifts in the future. Longer-term objectives assessing trends, poleward shifts, and climate relationships with spawning distribution would provide valuable insight into the future persistence of herring spawn in California (also discussed in Section 5.1). Such data may require detailed spatial records of spawn observations along the California coast. These data may include formal or ad-hoc data collection from spawn flights, anecdotal records, or other sources.

1.2.2 Maturity-at-age and fecundity

CDFW should consider studies that attempt to estimate maturity-at-age and whether that changes over time. Given that fish growth rates have changed dramatically over time (DFO 2015), there is no reason to assume that historical estimates of maturity-at-age reflect their current values. These data will be useful in any attempt to construct a stock-assessment and in translating information about YOY surveys to future spawning biomass forecasts.

Likewise, the reviewers recommend conducting higher frequency of female fecundity monitoring as size/age structure is changing. If data currently being collecting about fecundity are insufficient, CDFW should consider undertaking studies that attempt to estimate current maturity-at-age.

1.2.3 Spawning habitat availability

Herring in the San Francisco Bay utilize eelgrass (*Zostera* spp) and red algae (*Gracillaria* spp) in addition to other physical and biological spawning habitat. Surveys are conducted to assess habitat availability in terms of kilogram per square meter. However, how and if this information is utilized to assess total availability of habitat, what current trends are, and how it compares to other habitat surveys (of eelgrass beds, for example) remains undescribed. The reviewers recommend at least providing some context and background addressing these questions given that these data are on hand.

2. EVALUATION OF SPAWNING STOCK BIOMASS THRESHOLDS AND HARVEST RATES

The draft FMP's aim is to provide an adaptive management strategy for the California Pacific herring fishery that achieves 'sustainability' by implementing a harvest rate of no more than 10% of spawning stock biomass (SSB) each year. However, it is not currently possible to estimate in-season SSB due to management resource constraints. Therefore, quotas for next season are set based on a percentage of the previous season's SSB. This method assumes a relatively stable herring stock size from year to year, but herring SSB has exhibited higher interannual variability since the early 1990s. Consequently, the use of last year's SSB as a proxy for the coming year has become less useful over time. Recently, correlations between indicators of herring stock health and environmental indices have been used to develop a predictive model to estimate the coming year's SSB. This proposed predictive SSB model has been published in a peer-reviewed journal (Sydeman et al., 2018) and at least partially addresses the problem of using last year's SSB as a proxy for this year's SSB by incorporating a

recruitment index and environmental indices. As proposed in the draft FMP, the harvest control rule (HCR) framework is based on this predictive model and the presented management strategy evaluation (MSE) for the San Francisco Bay herring stock. This review did not assess the HCR based on the empirically-based SSB, which would require additional review.

Overall, the review panel is fairly confident that the proposed predictive SSB model as applied in the proposed HCR is appropriate to meet the ecological management objectives of the fishery, given relatively conservative targets for exploitation rates which should be robust to sampling error and population variability (provided the potential problems with fecundity and weight described above are addressed). However, it was more difficult to determine if this HCR as proposed would meet 'economic viability' objectives because no quantitative information was provided on how economic viability was determined, nor were economic objectives directly incorporated into the MSE (catch and variability were included, but these are indirect measures of economic viability).

Below are the review panel's specific evaluations of: the application of the proposed predictive SSB model (Section 2.1), the interpretation and application of MSE results (Section 2.2), and considerations for future investment (Section 2.3). Sections 2.1.1 and 2.2.1 contain recommendations relevant to the proposed predictive SSB model and MSE, respectively, that should especially be considered before adopting the FMP. Sections 2.1.2 and 2.2.2 contain recommendations that could improve management of the fishery but are not imminent priorities and/or may require longer-term investment and research.

2.1 Application of predictive spawning stock biomass (SSB) model

Generally, reviewers view switching from the current empirical method to the proposed predictive SSB model (Sydeman et al., 2018) as appropriate for a number of reasons: 1) the model predicts SSB better than the current methods, 2) recruitment, or YOY, surveys provide valuable information on year-class strength that biomass information does not, 3) assuming the current year will be like the previous year is a poor predictive strategy when temporal auto-correlation is low (recently auto-correlation in SSB has decreased), and 4) more accurate predictions resulting from the proposed predictive SSB model reduce the likelihood of over- or under-exploiting the stock. Although these benefits make the proposed predictive SSB model a clear winner over the empirical method, there were several issues raised and the review panel has concerns that the proposed predictive SSB model may not be the best model to use for the longer-term.

2.1.1   Key Recommendations

Demonstrate the expected efficacy of the predictive SSB model in management

The proposed predictive SSB model was not used in the MSE, consequently it is not clear what the projected performance of this model will be. There would be stronger justification for using this model if it had been used in the MSE (discussed more in Section 2.1.2).

Clarify the reasoning for abandoning the stock assessment model in favor of the predictive SSB model

Reviewers understand that the last assessment was not approved, due in part to difficulty in estimating a stock-recruit curve. However, difficulty in estimating a stock-recruit curve should not be a barrier to building an assessment model and is quite common. For example, herring data in British Columbia has a similar structure (DFO 2015) and has effectively estimated a Bayesian age structured assessment model, as have others (Hulson 2007). Information on the age- and size-structure of the population is lost in the proposed predictive SSB model, but an assessment could present this information in a useful format. Consequently, further discussion about the stock assessment's short-comings and its comparison to the proposed predictive SSB model would be useful to ensure the best model is used in management (explored further in Section 2.2).

Explicitly consider and report uncertainty in management outcomes

Uncertainty enters the management process in many places--e.g. observation error in the survey data, process error in environmental forcing, and implementation error in management. Many of these sources of uncertainty were incorporated into the MSE, yet others were not (like the error surrounding the output and input of the proposed predictive model--arguably one of the most influential sources of error in this management strategy). The reviewers emphasize the need to account for and communicate this uncertainty, and mention other places uncertainty could be important in other recommendations below.

2.1.2   Other Recommendations

While the reviewers believe the proposed predictive SSB model will be an improvement in California Pacific herring management, the panel note potential improvements to the proposed predictive SSB model that should be considered in the model's application to management:

Further explore the phase-space between the variables used in the predictive model

The phase-space between the variables used in the proposed predictive SSB model has not been fully explored (i.e. there are values for environmental variables or the recruitment index that have not been observed, and therefore do not have a corresponding observation of spawning biomass with which to make predictions). Consequently, predictions within unexplored regions of the phase-space cannot be made with any certainty. A sensitivity analysis using simulated data fed to the proposed predictive SSB model (and into the harvest control rule in a full-feedback MSE as noted again in Section 2.2.2) would be useful to further evaluate the performance of the model. An example of a potentially problematic scenario is one in which the YOY survey reports zero recruitment, but environmental conditions are ideal which could lead to SSB estimates that are highly uncertain and uncredible. Exploring and accounting for this uncertainty will be critical to effective management.

Carefully consider assumptions of the model

Assumptions of the model (e.g. additive effects of temperature; assumed Gaussian errors rather than log-normal; errors in variables; jack-knifing vs. k-fold cross-validation) would also be useful to carefully scrutinize and provide justification. Justifying the assumptions of the model would bolster confidence in the output of the proposed predictive SSB model and its use in management.

Directly address and consider uncertainty inherent in predictive SSB modeling and data inputs

Using linear temperature forecasts has the potential to produce conditionally biased results. The existence of such bias can be partially examined using existing data by examining trends in out-of-sample error in the forecast associated with temperature. Consideration of model averaging for the forecasts may be useful in the proposed predictive SSB model. The difference in Akaike Information Criterion (AIC) between the model with-versus-without sea surface temperature (SST) is small (3 AIC units) suggesting model uncertainty is high and the utility of environmental covariates is low. Additionally, the proposed predictive SSB model does not consider the uncertainty in the estimates of SSB and YOY fed to the model. State-space models would offer the ability to do this.

2.2 Management strategy evaluation to inform the harvest control rule

The outcomes of management strategy evaluations depend upon the input parameters. While many of the input parameters for the presented MSE are not well known, the outcomes of the chosen harvest control rule (HCR) configurations were somewhat predictable and the relationship between their outcomes (e.g. rankings of total yields and closures) would likely be preserved for a range of input parameters. In general, while the review panel would not necessarily recommend choosing a different HCR, some concern was expressed related to the scientific backing for the input parameters, performance metrics, model structure, and a relatively high closure rate for the chosen HCR (discussed below).

2.2.1 Key Recommendations

Incorporate the predictive SSB model into the MSE

One of the key purposes of an MSE is to test the performance of "estimation models" (here the predictive SSB model) to be used in management. Per Appendix 11 describing the MSE, this was not done here. Therefore, the reviewers cannot effectively assess how the proposed predictive SSB model performs relative to the empirical model (or other potential assessment methods). In order to strengthen the justification for switching from the current empirical method to the proposed predictive SSB model, the MSE should be run using the proposed SSB model.

Explain the process for selecting final candidate HCRs for the MSE

The review panel understands that the stakeholder engagement process was key in determining the biomass cut-offs and final five candidate HCRs. It would be helpful to include in the draft FMP a description of the full range of cut-offs and HCRs considered and how those were bounded based on stakeholder discussions. The five HCRs run through the MSE seem reasonable given the materials available to reviewers during the review, but it would be useful to know what pitfalls were identified previously and why certain HCRs were eliminated.

2.2.2 Other Recommendations

While the reviewers have a range of additional observations and suggestions related to the MSE, they do not believe these should necessarily impact the overall results or the implementation of the FMP.

Consider different/additional input parameters

Parameters determining the productivity of the stock drive the results of these analyses, but they are not well known. The conditioning of the operating model should be considered more closely--based on the information provided to reviewers, the simulated fishing mortality rates over the historical period exceeded 8.0 (Appendix 11 Figure B3), which is questionable given other information on the fishery. Risks to the fishery other than fishing

(e.g. risk of oil spills) should also be considered. Additionally, a sensitivity analysis for out-of-bounds predictions would be useful to understand the performance of the HCR to unexplored portions of the phase-space.

Consider different/additional performance metrics

The key objectives of the draft FMP appear to be economic viability of the fishery and minimizing ecosystem impacts, yet the performance metrics did not reflect these two goals well. For highly variable stocks, like Pacific herring, the metrics currently used in the MSE (B_{MSY} and B_0) are poorly defined and consequently do not provide very useful information for management. The key metric for economic viability presented in the completed MSE was closure rates, yet it would be useful to consider others to understand and communicate the different impacts of management. For example, projecting vessel profits based on projected prices and costs of fishing under different management strategies could provide tangible impacts of alternate strategies.

Additionally, there is no metric for ecosystem impact currently included in the presented MSE. There are many ways of approaching this metric, but a potential method would be estimating the size of predator populations that could be supported by the stock after fishing and use the mean/median predator population and its variance as an indicator. In general, the reviewers would have liked to have seen parameters that influence the outcome of the MSE determined by data, and performance metrics that more closely aligned with the goals of the fishery.

Revisit closure rates and the potential impacts on herring population and the fishery

Based on the MSE, the proposed HCR results in a closure rate of 20%. As the precautionary harvest rate already accounts for stock sustainability and variability due to environmental conditions, reviewers were surprised to see a closure rate this high. An in-depth discussion of what specifically is driving the closure rates (given an apparently conservative HCR), if these conditions appear to mirror reality, and how this impacts the economic viability of the fleet would be useful to build robustness and confidence in the HCR. The reviewers are somewhat concerned with what might happen if there was a closure of the fishery two years in a row (which has a relatively high probability of happening in the not-too-distant future with this closure rate), and if this closure rate actually helps to achieve the stated goals of sustainability and stock rebuilding beyond the precautionary harvest rate. The reviewers acknowledge that the decision about what closure rate is "acceptable" is a management decision, but if moving ahead with the proposed HCR, the draft FMP should more explicitly address the implications and uncertainty contained within this predicted closure rate.

2.3 Longer-term recommendations

Revisit exploring a stock assessment

An impressive amount of biological information exists for the San Francisco Bay herring stock. The development and maintenance of a stock assessment model would benefit CDFW by synthesizing and integrating that information into a format useful in management. A stock assessment would allow a framework for managers to ask more complicated questions about changes in management. For example, changes in selectivity could be useful management levers (e.g. changing mesh sizes), but with the proposed predictive SSB model, it is not clear how changes in selectivity might impact management advice or the sustainability of the fishery.

Stock assessment development is an iterative process, so previous rejections of proposed stock assessments should not discourage future efforts. It may be worth first doing a cost benefit analysis for developing the assessment to the point that it is useful in management. Although it is not immediately clear how much more precise and accurate estimates of SSB from a stock assessment would be compared to the proposed predictive SSB model given the life history and available data streams, the review panel agrees revisiting a stock assessment would be a worthy future investment. An explicit side by side comparison between the developed stock assessment model and proposed predictive SSB model in a management strategy evaluation would be useful to understand the costs and benefits of each model.

Iterate the predictive SSB model and perform regular model validation

If the proposed predictive SSB model will be the tool used for the foreseeable future in management, a routine process to evaluate the performance of the model should be developed. The model should be updated yearly with new data, and model accuracy should be reassessed.

3. EVALUATION OF ECOSYSTEM INDICATORS

Pacific herring play an essential part of the California Current Ecosystem as a forage species. As preliminary quotas in the proposed HCR are developed using a single species model to understand impacts to San Francisco Bay populations of Pacific herring (described and reviewed above), they do not explicitly take into account the current status of alternative forage and predator indicators. In recognition of this, a novel approach to incorporating ecosystem indicators was developed as part of the draft FMP. Indicators include: 1) herring productivity, 2) alternative forage availability, and 3) predator populations. The goal of the indicators described in the decision matrix (Table 7-2) is to signal poor conditions when additional precaution in management may be warranted, or healthy conditions when quota may be increased. As proposed, this matrix would provide qualitative guidance to CDFW to determine if adjustments to the preliminary quota are necessary (Figure 7-2). The decision matrix was developed to be adaptive and updated by CDFW as needed to reflect the best available science. Reviewers focused on rationale behind the interpretation and inclusion of these ecosystem indicators in setting final quotas.

Section 3.1 contains the reviewers overall assessment of the ecosystem indicators decision matrix and key recommendation. Sections 3.2 includes recommendations the review panel feel are critical to improving the robustness of the proposed approach, but may require longer-term work.

3.1 Overall assessment

Develop quantitative thresholds, calculate historical scenarios, and provide additional evidence linking ecosystem indicators to specific ecological responses to support using ecosystem indicators to adjust quota

Ecosystem based management approaches are widely recognized as an important next step in both State and Federal fisheries management approaches. Federally, ecosystem indicators are largely used as information in ecosystem status reports broadly (e.g. Harvey et al., 2017), or to inform fisheries ecosystem plans for a specific stock (e.g. Levin et al., 2018). In these scenarios, the environmental information is not currently used in a decision support tool to adjust quotas, but provide the general context on what to expect in the given year and in upcoming years. In addition, these narratives often can provide context for past years where stock size estimates may have been higher or lower than expected.

The ecosystem indicators section of the draft FMP is quite useful in understanding the broader ecosystem context and the review panel is encouraged that efforts are underway to include this information. Incorporating ecosystem indicators is challenging and few successful implementations of ecosystem based methods exist to guide CDFW in their efforts. Given the novel ecosystem approach developed for the San Francisco Bay herring stock, the draft FMP has the potential to lead the way for future ecosystem-informed FMPs. While admirable and ambitious, the reviewers have reservations regarding the proposed framework as it stands, for incorporating ecosystem indicators into the HCR. The proposed rules are vague and not empirically derived from quantitative analysis or tested with MSE, and appear to lack a transparent process for proposition and adoption of deviations from the HCR from year to year. As a result, the reviewers recommend working to build a more transparent, quantitatively based, and tested ecosystem approach.

Reviewers recommend developing quantitative thresholds, calculating historical scenarios to ensure that the thresholds are adjusting the quota as envisioned by CDFW and stakeholders involved, and providing additional evidence linking ecosystem indicators to specific ecological responses. Generally, ecosystem indicators are useful to pursue, but it is equally important to ensure that effort be spent solidifying the single-species research. As single-species methodologies are the building blocks for ecosystem based approaches, focusing on the single-species details (especially economics) can also answer some of the key questions lingering about the impacts of the ecosystem decision matrix. If CDFW decides to incorporate ecosystem indicators in the interim, the FMP should outline the transparent process by which ecosystems-based deviations from the HCR are considered and justified.

Overall, given that the harvest rate cap implicitly considers some ecosystem conditions, the HCR preliminary quota setting serves as a valid approach. Developing thresholds for incorporating ecosystem indicators and a formal process for adopting them would support their inclusion directly in the HCR. Until then, ecosystem indicators could be used, as in Federal fisheries examples, as general context when setting quotas on what to expect in the given year and in upcoming years (more detail below).

3.2 Recommendations to incoporate ecosystem indicators moving forward

This section includes recommendations that are important for building a more robust approach. Addressing these recommendations would improve the application of the ecosystem indicators and the management of the fishery, and may require longer-term investment and research.

Evaluate performance of HCRs corresponding to the bounds of green, yellow, and red conditions (Figure 7-2) within MSE framework

As a first step, the review panel recommends making it more transparent how ecosystem indicators would link to "green," "yellow," or "red" conditions (Figure 7-2). It would be informative to evaluate performance for HCRs roughly corresponding to these limits to understand how ecosystem conditions and a given increase or decrease in quota to these levels would relate to the current performance metrics. Even without explicit linkages between specific ecosystem indicators and potential quota adjustments, the reviewers recommend that these adjusted quotas be formally run through the MSE.

Consider developing ecosystem status reports to support the FMP

The existing HCR and proposed ecosystem indicators could be used down the line to directly inform ecosystem-level advice. In the meantime, ecosystem status reports, also called fisheries ecosystem summaries, can provide a snapshot and synthesis of the state of fisheries, communities, and the broader ecosystem. These summaries can provide ecosystem considerations to support individual fisheries management plans, and serve as the backbone of broader ecosystem-wide assessments. The summaries can describe environmental, social, and economic states and their potential impacts on commercially important fish species.

Develop statistically- or expert-based thresholds that link indicator level to action to improve reproducibility and transparency in how ecosystem-indicators could lead to adjustments in quotas

The main concern about using the proposed decision matrix is its lack of defined thresholds that link indicator levels to action. The proposed HCR (black line in Figure 7-2) is a conservative approach towards setting herring harvest guidelines that takes into account some of the ecosystem considerations of harvesting forage fish. The explicit ecosystem indicators chosen in the decision matrix make ecological sense, but there was concern raised that the qualitative nature of the decision-making approach as it is proposed is not based on strong enough scientific links between a given indicator, the ecological response, and the proposed quota adjustments and could lead to criticism and unexpected outcomes. In turn, the review panel recommends developing limits to allow reproducibility and transparency in how ecosystem indicators could lead to adjustments in the proposed quotas to accomplish the goal that quotas can be adjusted by the CDFW's Director as needed without regulatory changes.

To then assist in linking ecosystem indicators to management action, the review panel suggests that CDFW could build a decision tree, that highlights at what established ecosystem thresholds HCR adjustments would be made. Other qualitative management indicators used for single species management, such as Productivity Susceptibility Analysis (Patrick et al., 2010), provide semi-quantitative scoring, and developing something analogous for the decision matrix would provide a transparent way to develop a score for the number of indicators that are low/ medium/high within each of the broad categories, with a decision tree/table for when or how much quota would be reduced (or increased) given a certain ecosystem score. Table A5 does this for the Alternative Forage Indicators, but the other two components of the decision matrix (Herring Productivity and Predator Indicators) do not have a scoring system developed. Additionally, having a sense of how past conditions would score under any threshold would be useful to make sure that the tool is performing as expected.

An additional approach towards setting thresholds and decision rules could be to incorporate stakeholder involvement while setting the thresholds and potential quota adjustments. For example, such an approach could mirror recent efforts (Draft Risk Assessment and Mitigation Program developed by the California Dungeness

Crab Fishing Gear Working Group) that have developed a framework based on objective criteria, including ecosystem thresholds, to assess whale entanglement risk by Dungeness crab gear. This process brings together a group of scientists, managers, and stakeholders to assess information including ecosystem conditions that can lead to low, medium, or high level of risk to whales. A similar approach for the San Francisco Bay herring fishery could be useful by gathering a diverse set of experts to inform thresholds and build stakeholder engagement and trust in the resulting thresholds.

Regardless of how ecosystem indicators are potentially incorporated into adjusting quotas, more description of the decision-making and stakeholder processes of moving from preliminary HCR to using ecosystem indicators to shift quota, such as a flowchart, would be a critical addition to the draft FMP.

Perform a retrospective analysis to examine how quotas would have been adjusted in past years

The review panel recommends performing retrospective analyses to examine how often quotas would have been adjusted in past years under proposed management scenarios. For example, which years and what overall percentage of time would the quota have been adjusted up or down based on past ecosystem conditions. This would help CDFW and the broader stakeholder community understand what role the ecosystem indicators would likely have in adjusting quota and would increase the transparency of the consequences of choosing an updated quota based on the ecosystem conditions.

Provide additional evidence linking ecosystem indicators to specific ecological responses

While the ecosystem indicators seem logical, the reviewers would like to see additional documentation of studies linking each indicator to ecological impacts, and a discussion of the degree of confidence in that inference. Based on how indicators are related, composite forage indices or decision trees linking conditions of multiple indicators may be appropriate to consider.

Some technical questions about the indicators remain, for example:
- Is it desired to use indicators that are NOT correlated, or would it be desirable that they are reflecting the same phenomenon and therefore several of them would provide greater weight of evidence that that particular phenomenon was occurring?

- The forage indicators for market squid and groundfish appear to reflect poor conditions only if also found in concert with low pelagics. This suggests a composite index might be more appropriate (or a decision tree where only consider squid and groundfish being low IF pelagics are also low).

- Also, given the uncertainty and lack of data on diets from the winter, weighting the forage indices by the number of predators in which the item appeared (as was the originally attempted weighting scheme) appeared to be arbitrary. Do we know if any of the predators actually specialize, or if they are generalist and likely prey switch? If the latter, then some sort of composite forage index might make sense, assuming all predators access it.

Conduct an MSE that more explicitly includes ecosystem indicators

An MSE that includes ecosystem indicators, perhaps in place of those relative to B_0 and B_{MSY} as performance metrics (as discussed in Section 2.2.2) could provide more information and help CDFW understand the impacts of ecosystem conditions on the fishery. For example, combining an MSE including ecosystem indicators with economic analysis could provide insight into whether the most extreme scenarios (i.e. HCR rules under best versus worst ecosystem indicators) are expected to have significant economic impacts.

Set more quantitative goals for the fishery

The review panel recommends setting more quantitative goals, or "targets," for the fishery. Many of the goals throughout the draft FMP are well stated qualitatively, but lack quantitative targets to measure against. In

many cases, management can only react to stock fluctuations, rather than determine them by attempting to maintain biomass around some target. The San Francisco Bay Pacific herring stock seems to follow this sort of pattern—recruitment is largely environmentally driven. The balance to be struck in volatile fisheries like this is one between maintaining a fleet such that booms can be capitalized upon and a fleet small enough to weather periods of poor productivity. Without quantitative targets to measure against, it may be difficult to maintain management objectives.

4. SCIENCE SUPPORTING ADDITIONAL CONSERVATION AND MANAGEMENT MEASURES

The draft FMP describes the history and rationale for the management measures that have been employed in the California Pacific herring fishery. While quotas are the foundation for ensuring sustainability in Pacific herring stocks, the draft FMP describes the additional management measures CDFW employs to provide additional safeguards for the stock. These other management measures include: 1) effort restrictions (which include permit consolidation and fleet capacity limits), 2) gear restrictions, 3) spatial, temporal, and seasonal restrictions, 4) size and sex, 5) prevention of bycatch, and 6) reduction of habitat impacts.

Reviewers concluded that a sloped HCR with a 10% maximum exploitation rate is likely to minimize the impact of the fishery on both the stock and the ecosystem. Thus, using catch restrictions as the main management measure is likely to be effective, and streamlining the temporal regulations, as is proposed, so that all populations have the same start and end date will likely make this management measure more enforceable. The additional conservation measures are likely to further support sustainability of the San Francisco Bay stock and the review panel has only minor recommendations that should be addressed before adoption of the FMP.

4.1 Key recommendations

Provide further rationale for mesh size limits

Mesh limits are often a good idea, but there does not seem to be a quantitative approach for determining what is best included in the analysis. Data on the initial (160-170mm) and fully selected sizes (180-185mm) is given, but the review panel recommends a selectivity ogive, and explicit linkage age (using Figure 3-7) to inform how it relates to age-based selectivity goals.

Expand discussion of implications of targeting age 4+ on stock sustainability

While the recovery of herring age structure shown in Figure 6-2 suggests that the current mesh size is not resulting in major age truncation, targeting age 4+ may still result in evolutionary changes in growth, maturity, fecundity, and reproductive behaviors. Reviewers suggest adding discussion about the implications of this for stock sustainability.

Expand description of effort restrictions and its link to desired tonnage goals

An expanded narrative of the stakeholder process and the rationale for relating the number of permits to maximum quotas was provided to the reviewers by CDFW during the review and should be incorporated into the draft FMP.

Set more quantitative targets for when certain rules will be reconsidered

Some examples of vague, or difficult to evaluate, statements that would benefit from clear, quantitative targets include: "should conditions change in the future," "some changes to the season dates are warranted," and "should the recreational sector continue to grow." CDFW should work to develop thresholds that determine when these rules will be reconsidered.

5. FUTURE RESEARCH AND METHODS

The draft FMP is designed to provide a comprehensive and adaptive management strategy for the California Pacific herring fishery. To support this goal, the draft FMP identifies additional management needs and future research that would assist CDFW in improving assessments and management in the future. Throughout this report, reviewers have identified additional research and data needs that would support more robust management of the fishery, some of which are mirrored in the "Additional Management Needs and Future Research" chapter of the draft FMP. Recommended future research and data needs not already outlined in the draft FMP should be added to the relevant section before adoption.

Overall, as there is a wealth of data for the San Francisco Pacific herring population and the California Current Ecosystem, reviewers recommend prioritizing the synthesis of existing data and information before allocating resources to collecting additional data, except for recruitment data and in the scenario where anomalous conditions require additional data.

5.1 Key recommendations

Prioritize sampling for recruitment

As stated previously, reviewers commend the proposed SSB model and HCR for considering recruitment in setting annual quotas. This is a crucial improvement on the previous method for setting quota and should be prioritized in order for CDFW to successfully reach their management goals (also discussed in Section 1.1.4). If these data become unavailable, SSB estimates are not likely to be as accurate.

Formally analyze predator-prey interactions to inform incorporation of ecosystem indicators

A major component of the draft FMP is the ecosystem considerations, with a focus on predator-prey dynamics. This should likely be a future focus of research, with an aim to identify whether and when prey provide a limiting factor. Questions that should be answered include:

- Is there evidence that predator populations do fluctuate in response to the available forage (or that there is a cutoff below which predator indicators decline)?
- Is there any evidence that, when small pelagics are low in abundance, that abundant herring become a focal prey item or that there is prey overlap? For which predators?
- Are these the same predators that might show occasional prey limitation?
- Does the spatial distribution of predators, prey, and herring play a factor?

Diet analysis, historical analysis, and expert elicitation all might provide fruitful avenues to answer these

questions. As noted in the draft FMP, the California Current Integrated Ecosystem Assessment has synthesized a number of indicators of forage, predator status, and ecosystem conditions, and many of these time series are available since the early or late 1990s. Incorporating these data further into the ecosystem decision matrix as well as a formal analysis of the linkage between forage fish and predators could improve the capacity and transparency of including the ecosystem considerations in the setting quotas.

Better characterize spatial variation in response to environmental change

At a minimum, coarse monitoring of stocks in other California locations may help understand whether stocks are responding differentially to environmental change. If it is to be used for this purpose, provide more detail about the Rapid Spawn Assessment Method, and its performance when applied to the relatively data-rich San Francisco Bay stock (as discussed in Section 1.1.3). Because the herring population in San Francisco Bay represents the southern end of their range, there is the possibility that increased temperature stress and/or range shifts may affect this population. As such, explicit monitoring of all California herring populations in response to environmental change should be on the radar for future monitoring or research. This understanding would allow the fishery management system to be more climate-ready.

5.2 Longer-term recommendations

Better characterize interannual spatial dynamics of stocks

Much of the concerns about ecosystem dynamics are complicated by spatial behavior before and after spawning. That is, where do herring go to feed, and what feeds upon them when they are away from spawning areas? Characterizing these dynamics might be a key future research endeavor to identify which ecosystem indicators should actually be considered given the spatial overlap of herring with their prey and predators. CDFW may consider using high resolution, polymorphic SNP markers that are now available (E. Petrou and L. Hauser, in prep) to evaluate spatial structure of the stock (as discussed in Section 1.2.1).

Better track, consider, and integrate recreational take into quota setting

As mentioned in the draft FMP, there is currently no data on the magnitude of catch in the recreational sector of the California Pacific herring fishery. Moving forward, it will be important for CDFW to quantify recreational catch so that it can be considered in setting quota. Currently, it is not clear how recreational take impacts the herring stock under the proposed HCR. Accounting for varying levels of recreational catch in an MSE and integration of this information, when available, will result in a more robust management strategy.

Identify external ecosystem factors that affect herring populations

What are the impacts of cumulative stressors (e.g. temperature together with water quality) on herring stocks? A broader MSE that takes into account external stressors will help identify where the HCR framework may fail.

Develop a sampling program to directly estimate maturity, fecundity, growth, and mortality

These demographic parameters may underlie the changes in size-at-age in San Francisco Bay. Knowing which of these drivers is operating can help identify appropriate management action to counteract these effects.

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Appendix A: Terms of Reference

1. Introduction

1.1 CDFW Management Context

Pacific herring populations support important commercial and recreational fisheries in California state waters. Herring are a schooling species found throughout California nearshore ecosystems during spring and summer and migrate to bays and estuaries to spawn from November through April. They play an important role in the California marine ecosystem as a forage species for a wide suite of predators, including marine birds and mammals and are among the top forage species in terms of their proportion in predator diets, making them an essential food source for predators on the West Coast. The San Francisco Bay herring population supports a valuable fishery for herring roe (kazunoko), and a smaller herring-eggs-on-kelp (komochi or kazunoko kombu) fishery. San Francisco Bay also supports a limited commercial fresh fish and recreational fishery.

A primary goal of fishery management under the Marine Life Management Act (MLMA) is to ensure that fishing levels are sustainable and do not result in an overfished stock. While the commercial herring fishery is considered well managed, even with a very precautionary management approach, concerns about changing ocean conditions, sea-level rise, loss of spawning habitat, stakeholder interest, and a need to better understand spawning and stock fluctuations and their role as a forage fish have prompted the development of a fishery management plan (FMP). FMPs assemble information, analyses, and management options to guide the management of the fishery by the California Department of Fish and Wildlife (CDFW) and Fish and Game Commission (Commission). The FMP becomes effective upon adoption by the Commission, following their public process for review and revision. Thus, it is important for the scientific underpinnings of the draft FMP to have undergone independent review prior to submission to the Commission. External, independent peer review of the scientific underpinnings of the FMP is one way to provide the Commission and stakeholders assurances that the FMPs are based upon the best readily available scientific information, as set forth under the MLMA. The Ocean Protection Council (OPC) has provided funding to complete the peer review process for the Pacific herring FMP.

1.2. Review Process Goals and Objectives

Ensuring the best use of best available information in fisheries management is an important tenet of the MLMA. The MLMA identifies external scientific review as a key tool to ensure management decisions are based on the best available scientific information. CDFW is committed to incorporating the best available scientific information into fisheries management through a peer review process.

Scientific and technical peer review (review) is widely applied across numerous technical disciplines to assure products are of high quality, reflect solid scholarship, and that the information contained is accurate and based on rigorous, sound scientific methods (OST 2016). In any review, Ocean Science Trust's (OST) intent is to provide an assessment of the work product that is balanced, fairly represents all reviewer evaluations, and provides

feedback that is actionable. When building a review process, OST seeks to balance and adhere to six core review principles: scientific rigor, transparency, legitimacy, credibility, salience, and efficiency. These principles ground the review and shape the products that we develop.

As such, the goals and objectives of the FMP review process are to:

1. ensure that the science underpinning the FMP represents the best available scientific information and is appropriately used to inform a harvest control rule;

2. follow a detailed calendar and fulfill explicit responsibilities for all participants to produce required reports and outcomes;

3. provide an independent external scientific and technical review of the agreed upon sections of the herring FMP;

4. use review resources effectively and efficiently.

1.3. Review Coordinating Body: Ocean Science Trust

Ocean Science Trust is an independent non-profit organization working across traditional boundaries to bring together governments, scientists, and citizens to build trust and understanding in ocean and coastal science. We empower participation in the decisions that are shaping the future of our oceans. We were established by the California Ocean Resources Stewardship Act (CORSA) to support managers and policymakers with sound science.

For more information, visit our website at www.oceansciencetrust.org.

Contact information

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2. FMP Peer Review Scope and Process

2.1 Review Request

CDFW's purpose in asking for this review is to ensure the scientific and technical elements presented within the FMP provide a rigorous underpinning for management decisions and regulatory action. Ocean Science Trust is serving as the review coordinating body, and worked with CDFW to develop a scope of review that focuses on key scientific and technical components of the FMP where independent scientific assessment would add value (this document). The review is not intended to be a comprehensive assessment of the entire FMP or the proposed approach to management contained therein, but rather focuses on key components identified below. Components subject to review were determined using criteria from OST 2017 (here).

2.2 Scope of review

CDFW is seeking an independent assessment of the science underpinning the proposed management framework that will guide fishery management decisions for the San Francisco Bay Pacific herring stock. The framework uses a predictive model for determining herring spawning stock biomass mass and data collected by CDFW and others in the California Current Ecosystem. The review will focus on whether the available data and predictive model that underpin the proposed FMP management strategy are applied in a manner that is scientifically sound, reasonable, and appropriate.

The central question of this review is:

Given CDFW's available data streams and analysis techniques, are the applications of the analyses to the integrated management strategy scientifically sound, reasonable and appropriate?

Specifically, the review will focus on evaluation of the following components of the FMP:

- the accuracy of representation of existing literature on the biology of the stock and in the essential fishery information (Sections 3 and 5.2)

- the proposed spawning stock biomass thresholds and associated harvest rates underpinning the catch quota decision making process and signaling when the fishery may warrant management response; (Section 7.7)

- the decision matrix of ecosystem indicators and the rationale behind the inclusion of these ecosystem indicators in management; (Section 7.7)

- the science underpinning additional conservation and management measures (Section 7.8)

- identify research and methods needed to improve assessments and fishery management in the future (Section 8)

For clarity we note that the following are not included in the scope of the current review:

- the data collection protocol (Section 5.1), as it has been reviewed previously

- the new predictive model for spawning stock biomass (Section 7.6), as this is currently undergoing a separate peer review.

2.3 Process

Review Process Overview

- **Select a review mode.** A review process is selected in consultation with CDFW and the Ocean Protection Council by considering complexity, management risk, uncertainty, socioeconomics, level of previous review, and novelty (OST 2016; OST 2017).

- **Assemble review team.** Ocean Science Trust will convene a 3-4 member review panel composed of Ocean Protection Council Science Advisory Team members and other experts (see "Assembling a Review Team," OST 2016 and "assembling a review team" below for additional details).

- **Conduct review via a series of webinars.** Group webinars will allow CDFW to engage directly with reviewers at the outset to present the inputs, model methods, and application of analyses and provide two-way interaction to provide any additional clarity needed to complete the review. There will also be opportunities for independent deliberation and conversation among reviewers.

- **Develop and share final report.** Reviewers will contribute to the development of a final report, which will be made available on the OST and CDFW webpages.

Review Mode: Remote Panel Review

All meetings will take place via remote online meetings (webinars). At the outset of the review, OST will work with CDFW to develop detailed reviewer instructions that encourage focused scientific feedback throughout the process. Instructions will include directed evaluation questions and may delegate tasks for reviewers based on their individual areas of expertise. This document will be used to guide the development of meeting agendas and track progress throughout the course of the review. For each meeting, advance work will be required of participants (e.g. drafting responses to guiding questions) in order for all parties to come prepared for

meaningful discussions. OST will notify CDFW of additional requested materials and data immediately following the first webinar.

Webinar 1: Initiation of Review

Ocean Science Trust will host an initial webinar to provide the review committee and CDFW staff an overview of the scope and process, and clarify the roles and responsibilities of each participant. CDFW will also provide a summary of the relevant management context to ensure reviewers understand the role of the review in the larger FMP development process, and how the outputs will be considered. The bulk of the webinar will then focus on a presentation by CDFW and FMP contractor on the scientific and technical components of the draft FMP. This webinar is an opportunity to develop a shared understanding of the tasks and allow reviewers to ask CDFW any clarifying questions about the review materials before they convene independently to conduct their technical assessment.

Webinar 2-3: Reviewers convene with OST to conduct review

Ocean Science Trust will convene approximately two remote one- to two-hour webinars with the review committee to conduct an in-depth evaluation of the components identified in the Scope of Review (above). In advance of each webinar, reviewers will be asked to prepare responses to guiding evaluation criteria questions specified in the review instructions. During each webinar, reviewers will discuss their findings and develop conclusions and recommendations within the context of these questions. Additional follow-up phone conversations may be scheduled as needed to complete the review. Outputs from each webinar, as well as reviewer responses to the questions, will guide the development of the final report.

Webinar 4: Final summary report feedback

Ocean Science Trust will host a final 1-hour webinar to gather final feedback and input from the review panel on the summary report. The review panel will be asked to review the draft summary report in advance of this meeting. This final meeting will provide a space for reviewers to voice any suggested edits or clarifications, and a chance to have a final discussion about results before sharing the final report with CDFW.

Management Preview

Ocean Science Trust will share the final summary report with CDFW for a management preview before the review results are published. There will be an opportunity for CDFW to ask clarifying questions of the review committee and for reviewers to make clarifying edits, as appropriate. This may occur via email, conference call or short webinar as time allows.

Assembling Reviewers

Transparency

Reviewer names will be published on OST's webpage for the review at the outset of the review; however, specific review comments in the final review report will not be attributed to individual reviewers.

Selection of Reviewers

Ocean Science Trust will implement a reviewer selection process to assemble a review committee composed of 3-4 external scientific experts. Ocean Science Trust will consult with and solicit reviewer recommendations from CDFW, the OPC-SAT, as well as OST's own professional network among the academic and research community. Membership may include experts from academia, research institutions, and government agencies as appropriate to deliver balanced feedback and multiple perspectives. Reviewers will be considered based on three key criteria:

Expertise: The reviewer should have demonstrated knowledge, experience, and skills in one or more of the following areas:

- Fisheries biology, stock assessments and modeling, including spawning stock biomass analyses and application

- Herring and/or forage fish biology and ecology, with an understanding of California's coastal ecosystem and how forage fish stocks and linked populations (e.g. predators) respond to fishing pressure and climate change

- Developing and/or testing harvest control rules for fisheries management, including applying ecosystem based management

Objectivity: The reviewer should be independent from the generation of the product under review, free from institutional or ideological bias regarding the issues under review, and able to provide an objective, open-minded, and thoughtful review in the best interest of the review outcome(s). In addition, the reviewer should be comfortable sharing his or her knowledge and perspectives and openly identifying his or her knowledge gaps.

Conflict of Interest: Reviewers will be asked to disclose any potential conflicts of interest to determine if they stand to financially gain from the outcome of the process (i.e. employment and funding). Conflicts will be considered and may exclude a potential reviewer's participation.

Final selections for the review committee will be made by the OPC-SAT Executive Committee. Ocean Science Trust will select one member of the review committee to serve as chair to provide leadership among reviewers, help ensure that all members act in accordance with review principles and policies, and promote a set of review outputs that adequately fulfill the charge and accurately reflect the views of all members.

Transparency in the Review Process

To ensure transparency, reviewers will serve openly. Reviewer names will be published on Ocean Science Trust's review webpage at the outset of the review. However, to encourage unbiased and candid input, specific review comments will not be attributed to individual reviewers. Upon delivery of the final report to CDFW, the report will also be made public on the OST review webpage.

In addition, OST will host a public webinar briefing in which the review committee, led by the chair, will share the draft findings of the review process. The information sharing will be open to the public, and include a Q&A so the reviewers (and CDFW scientists) can answer questions. This meeting will occur after the completion of the final summary report.

2.4 Review Report (reference appendix template)

Ocean Science Trust will work with reviewers to synthesize reviewer assessments (responses to the review instructions and input during webinars) into a cohesive, concise final written summary report. This review summary will be delivered to CDFW by late September 2018, and made publically available on OST's website. Reviewers may also provide individual in-text comments on the draft FMP which will be provided to CDFW for internal use. We acknowledge that reviewers may provide scientific recommendations beyond the given reviewer charge; such scientific recommendations will be honored and represented in the final summary.

2.5 Timeline

The review will commence in February 2018 with the expected delivery of a final summary report to CDFW in October 2018. A timeline is provided below.

Milestone	Feb	Mar	April	May	June	July	Aug	Sept	Oct
Review Preparation									
Develop and Finalize Terms of Reference	X	X							
Establish review panel		X	X						
CDFW delivery of draft FMP to Ocean Science Trust				X					
Conduct Review									
Webinar 1: Initiation of review				X					
Webinar 2: Essential Fishery Information; Spawning stock biomass thresholds; Additional management measures				X					
Webinar 3: Ecosystem indicators matrix; Future research methods						X			
Webinar 4: Final discussion and report feedback							X		
Finalize Summary Report									
Final report available online									X
Public sharing webinar with review panel members									X

3. Roles and Responsibilities of Peer Review Participants

3.1 Shared Responsibilities

All participating parties share the responsibility in assuring adequate technical and scientific review of the Pacific Herring FMP in accordance with the MLMA.

3.2 Reviewer Responsibilities

The role of the review committee is to conduct a detailed evaluation of the scientific underpinnings of aspects of the Pacific Herring FMP where external review will be valuable. The specific responsibilities of the review committee are included in the Review Instructions. The review committee may request additional information, data, and analyses as appropriate to support a comprehensive and useful review.

The review committee chair has, in addition, the responsibility to: 1) provide leadership among reviewers; 2) ensure that review committee participants follow the terms of reference and review instructions and guidelines; and 3) promote review outputs that adequately fulfill the charge and accurately reflect the views of all members.

The review committee is required to make an honest and legitimate attempt to resolve any areas of disagreement during the review process. Occasionally, fundamental differences of opinions may remain between reviewers that cannot be resolved. In such cases, the review committee will document the areas of disagreement in the final summary report.

Selected reviewers should not have financial or personal conflicts of interest with the scientific information, subject matter, or work product under review within the previous year (at minimum), or anticipated. Reviewers should not have contributed or participated in the development of the product or scientific information under review. Review committee members who are federal employees should comply with all applicable federal ethics requirements. Reviewers who are not federal employees will be screened for conflicts of interest.

3.3 CDFW FMP and Management Team Responsibilities

The Mission of the California Department of Fish and Wildlife is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. CDFW and the management team, including contractors, will participate in the review process as follows:

1. *Provide all relevant project documents, data, and supporting materials.* CDFW will identify and provide all project documents, data, and other information necessary for reviewers to conduct a constructive assessment. CDFW will work to ensure all related materials are clear and accessible to reviewers in a realistic timeframe and respond to additional requests in a timely manner.

2. *Constructively engage with reviewers and OST staff, and respond to data and other information requests in a timely manner.* CDFW staff and contractors most familiar with the draft FMP will engage in the process and be available to answer questions or present materials to the review committee as necessary. The CDFW Environmental Scientist, Ryan Bartling, and contractor, Sarah Valencia, have agreed to serve as the primary contacts during the review process. In order to adhere to review timelines, CDFW will respond to and provide feedback on requested materials from OST in a reasonable, mutually agreed-upon timeframe.

3. *Consider reviewer comments and recommendations.* CDFW intends to consider and incorporate reviewer feedback and recommendations into the FMP and supporting materials as appropriate.

3.4 Ocean Science Trust Responsibilities

California Department of Fish and Wildlife has requested OST to serve as the independent appointed entity to design and coordinate all aspects of this scientific and technical review. Ocean Science Trust will design and implement all aspects of the review process to meet management needs, including assemble and guide a committee of expert reviewers, conduct a review process that is on task and on time, schedule and host remote meetings as appropriate, work with reviewers to produce a written final summary report, and encourage candor among reviewers, among other activities. Upon completion of the review, the final report will be delivered to CDFW and made publicly available on the OST website. Throughout, OST will serve as an honest broker and facilitate constructive interactions between CDFW and reviewers as needed in order to ensure reviewers provide recommendations that are valuable and actionable, while maintaining the independence of the review process and outputs.

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