Managing for resilience in the face of climate change: a scientific approach to targeted oyster restoration in San Francisco Bay and Elkhorn Slough, CA

A project funded by the National Estuarine Research Reserve System Science Collaborative

FORMATIVE FEEDBACK FROM END-USERS ON MANAGEMENT APPLICATIONS OF NEW SCIENCE

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EXECUTIVE SUMMARY

The goal of our collaborative science project is to support Olympia oyster conservation and restoration efforts by providing end-users new information that will improve their decisions related to Olympia oysters. Targeted end-users for this project are those engaged in Olympia oyster restoration, policy, strategic planning, permitting or funding.

In April 2013, we held a workshop to share preliminary results of the new science with end-users, and to obtain formative feedback from them on the most important management applications of the new science. We solicited quantitative scores on management questions and products from the 28 end-users who participated, as well as qualitative input. End-users represented various regions (esp. central California, but also southern California, Puget Sound) and categories of engagement with oyster restoration (from on-the-ground implementation to planning to funding and permitting). Their scores were used to identify top priorities to serve as our focus for analysis and interpretation of the data and development of products to disseminate them. The results of the prioritization by end-users and our adaptation of project plans in response are summarized below, and will be shared with end-users through our project web-page, working group meetings, and individual meetings with key players.

Management questions

End-users prioritized eight potential management questions that can be addressed with our new science. Four questions received the highest scores:

> *Which sites currently support healthy and abundant existing oyster populations that are most likely to be sustainable in the long-term?*
>
> *Which sites supply a disproportionate amount of larvae to other sites, thereby acting as a source of larvae rather than a sink?*
>
> *Which sites are best for success and long-term sustainability of oyster restoration projects?*
>
> *Is an oyster restoration project done at site X likely to be successful?*

As a result of the high priority given to these questions by end-users, we will invest the majority of our data analysis and interpretation on them. This does not represent a major shift, since questions about site selection and connectivity were a major focus of the original grant proposal that funded this project, and directed the field data collection plan.

Two other questions were part of the original conception of this work, but received more moderate scores:

> *How do effects of climate-related stressors compare to those of other stressors?*
>
> *Can resilience of oysters to climate change be enhanced by decreasing other stressors?*

Our PI team is still committed to answering these questions, in particular through laboratory experiments. However, given the end-user feedback, we will invest less time in translating the findings into management products than we had originally intended. It is possible that our pioneering demonstration of the usefulness of climate change-related management guidance will

increase end-user valuation of such applications in the future. Our research into climate change impacts is also essential to informing site selection (especially questions 1 and 3) and informing sustainable restoration strategies. The laboratory data on responses of oysters to abiotic factors will enable interpretation of field data to assess site value, both in terms of current conditions and future projections.

Products

End-users prioritized six potential products (guidelines, site evaluations, decision-trees, regional maps, conceptual models, decision-support tools) that we could develop to disseminate the new scientific findings for management applications. Three products received the highest scores:

Guidelines (e.g. written documents providing management recommendations)

Site evaluations (e.g. tables comparing sites in terms of oysters and relevant factors)

Decision trees (e.g. dichotomous keys or flowcharts providing management guidance)

Since the project team does not have the resources to develop all six of the product options, we will focus on these three products scored as most valuable by the end-users. This represents a modification of our plans as originally outlined in the grant proposal. There, we indicated that we would develop formal decision-support tools to aid in site-selection. However, given the relatively low score received by this type of product, and the very high cost in staff time for development and testing (relative to simpler products such as guidelines and site evaluation tables), we will drop this product from our plans, along with the other two lower scoring products (regional maps, conceptual models).

Overall, the formative feedback received from these 28 key end-users will be instrumental in guiding the development of management applications from this collaborative science project.

PROJECT BACKROUND

An interdisciplinary team from the California Coastal Conservancy, UC Davis and the San Francisco and Elkhorn Slough National Estuarine Research Reserve initiated a three-year project funded by the National Estuarine Research Reserve System Science Collaborative in November 2011. This project is characterizing stressor levels at multiple sites at two California estuaries (San Francisco Bay, Elkhorn Slough), assessing oyster populations at these sites and connectivity between them, and examining impacts of individual and combined stressors in laboratory experiments. The goal is to improve sustainability of Olympia oyster restoration in the face of climate change, by providing restoration planning tools.

End-users engaged in oyster restoration, planning, permitting or policy have been involved heavily throughout the project, to ensure that management needs inform the science, and science feeds back into improved management. In January 2012, 48 end-users provided feedback through an electronic survey on priority questions, sites and stressors, shaping the design of the field monitoring and laboratory experiments. In January-February 2013, in-depth interviews were conducted with 15 targeted end-users to characterize their decision-making regarding Olympia oysters. In April 2013, a workshop was held with 27 end-users to obtain formative feedback on key management applications of the new data from this project (see below). We are sharing the results of this workshop (as summarized in this document) with end-users through our email listserv, project webpage, working group meetings and one-on-one meetings with key end-users. End-users will continue to be engaged regularly in this project, culminating in a summer 2014 workshop and dissemination of final products.

For more information about this project, see http://www.oysters-and-climate.org

WORKSHOP TO OBTAIN FORMATIVE END-USER FEEDBACK

The goal of our work is to support Olympia oyster conservation and restoration efforts by providing decision-makers new information that will improve their decisions related to Olympia oysters. We held a workshop in April 2013 to obtain formative feedback from end-users on this effort. In particular, we asked end-users to help prioritize

1) Questions: Which are the most important management questions that our new data can help answer?
2) Products: How can we make the data easy for end-users to apply to those questions?

Feedback on these two areas will critically guide where the project team invests effort on data synthesis and analysis (1) and on product development (2).

About 65 Olympia oyster end-users from San Francisco Bay and Elkhorn Slough were invited to participate in a workshop held on 17 April 2013 at the Coastal Conservancy in Oakland, CA. Of these, 27 attended the workshop (and 2 attended a small focus group with an abbreviated version of the agenda at Elkhorn Slough on 15 April 2013) (Appendix 1). The workshop was facilitated by Collaboration Lead Marilyn Latta and began with presentations by the project team on climate change predictions for the region (Ted Grosholz), an overview of the project (Matt Ferner), field monitoring design and preliminary results (Andy Chang and Chela Zabin), and laboratory experimental design and results (Brian Cheng). In the afternoon, there was a presentation on decision-support tools (John Rozum, NOAACoastal Services Center) and brief

case studies from other regions (Betsy Peabody, Puget Sound Restoration Fund, Danielle Zacherl, California State University Fullerton).

To obtain formative feedback, the majority of the afternoon of this workshop was spent asking participants to score questions and products using clickers that provided real-time graphic results of scores (Turning Point Technologies). After explanation and quantitative scoring of options for questions and then for products, there was open-ended discussion time.

The results of the quantitative scoring and qualitative input are summarized below.

TYPES OF END-USER PARTICIPANTS

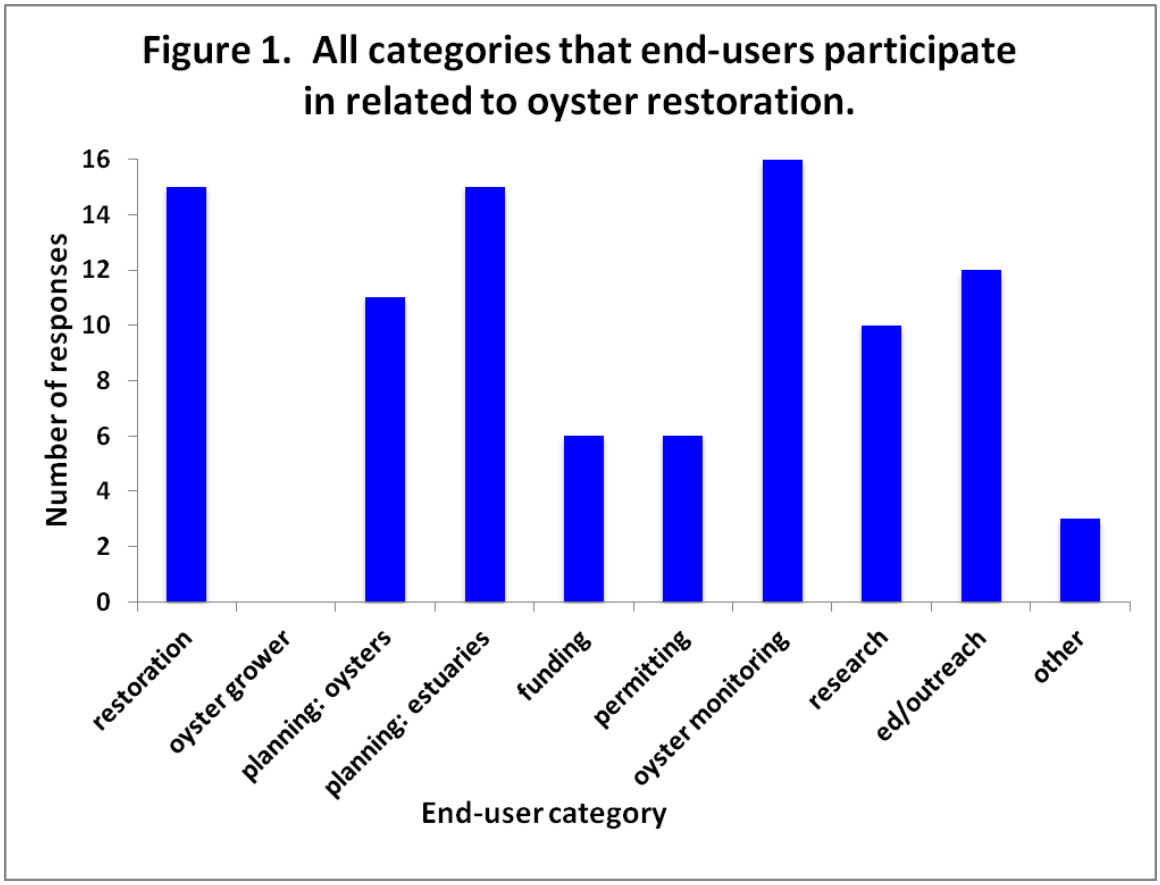
A total of 28 end-users provided feedback: 22 external participants who attended the workshop in Oakland (5 participants abstained), 2 who attended in Elkhorn Slough, and 4 who were members of the PI team as well as end-users. These end-users consisted of 20 who work primarily in the San Francisco Bay region, 3 from Elkhorn Slough, 4 from Southern California estuaries, and 1 from Puget Sound.

The participants were first asked to indicate all the categories that they partake in, related to Olympia oysters. The categories offered were:

1. "on-the-ground" Olympia oyster restoration
2. oyster farming (any species)
3. planning/policy for oysters
4. planning/policy for estuarine habitats
5. funding of oyster restoration projects
6. permitting / regulation related to oysters
7. monitoring of oysters
8. research projects on oysters
9. education / outreach about oysters
10. other / none

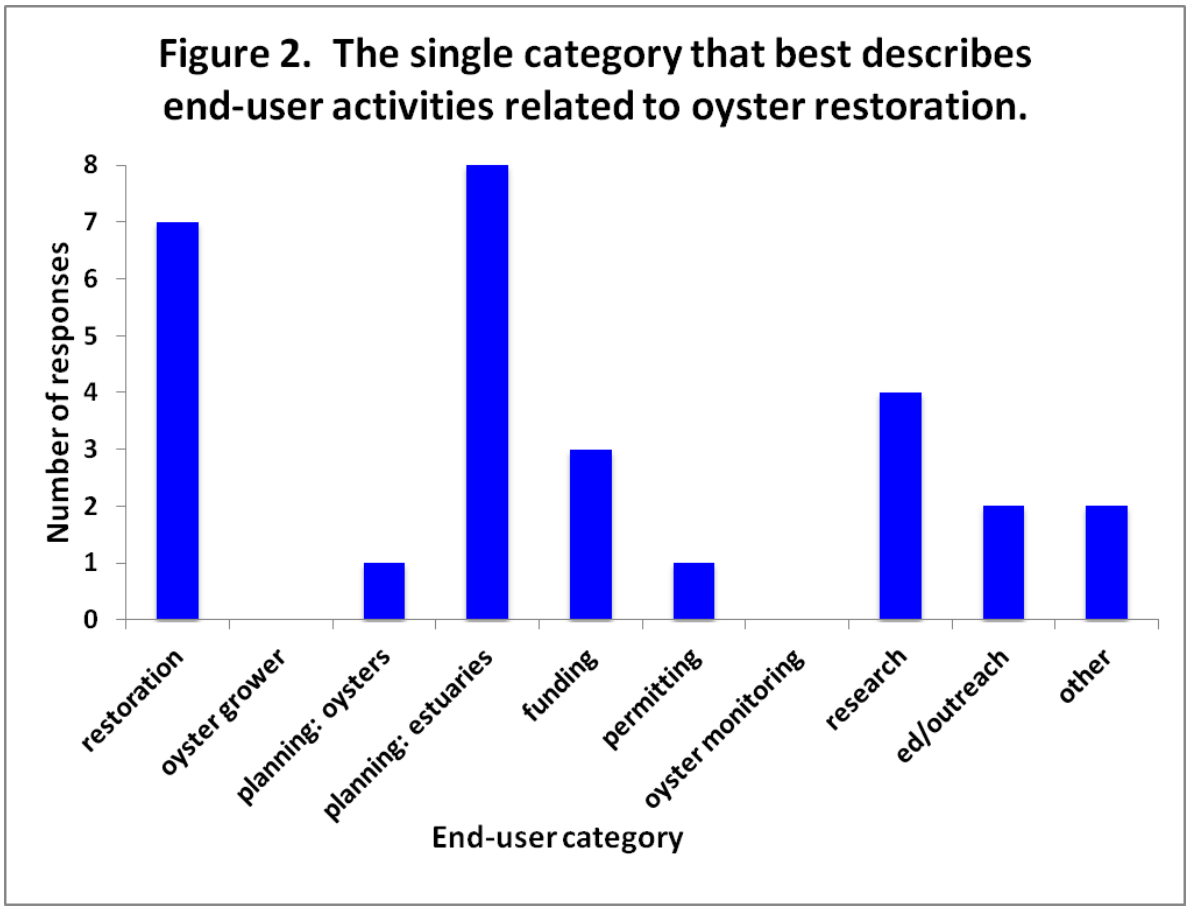
The results (Fig. 1) reveal a broad array of categories in which participants partake. All but four participants indicated they are engaged in multiple aspects of oyster-related work, selecting on average 3 out of the 10 categories. More than half of the respondents indicated they are involved in oyster monitoring, restoration, and estuarine planning efforts. Education/outreach, research, and planning for oyster restoration also ranked high.

Nearly everyone involved in on-the-ground restoration efforts was also doing monitoring (14 of 15 respondents) and most were also involved in education and outreach (9 of 15). This latter connection likely reflects the degree to which restoration projects have relied on community volunteers, coupled with the desire to build public support for ongoing restoration efforts. All but one of the respondents who are engaged in permitting and funding indicated that they are also engaged in planning for oysters and/or for estuaries more generally. There was no overlap of any of the categories with commercial oyster growers.



Next, participants were asked to select the single category that best described their biggest area of investment related to oyster restoration. (This single assignment was necessary in order to conduct statistical analyses of responses by participant demographic.) The results (Fig. 2) again revealed a broad spread of representation of different categories of end-users. Scoring revealed that category 1 (restoration) and 4 (planning for estuarine habitats) were represented by the most individuals. Categories 2 (oyster farming) and 7 (oyster monitoring) were not listed by any participants as their primary role with regard to oysters. (One person who works with a commercial oyster farm attended the beginning of the meeting, but had to leave before the polling and survey portion began.)

In the summary that follows, we averaged responses across all end-user categories. However, we also analyzed the data to explore differences among end-user categories (Appendix 2).



MANAGEMENT QUESTIONS INFORMED BY NEW DATA

Overview of management questions that could be addressed by new data

Our project team generated a list of management questions that could be addressed by the new data obtained from our investigations. We divided these into questions about where, whether, when, and how to do restoration. In all cases, these questions focus on what is best for the oysters – which sites support their needs best, which stressors are most harmful, what times of year are best for recruitment. Oyster needs are one very important component of management decisions: Olympia oyster restoration and conservation projects attempt to maximize oyster success. However, our team recognizes that much of management decision-making about oyster restoration and conservation centers around needs of humans rather than oysters. Decision-makers want to enhance ecosystem services. They want to do projects in areas where there can be active community involvement and education about the marine environment. They pursue projects that are beneficial in terms of partnerships and funding opportunities, and political factors also weigh strongly in their decisions. Our project data do not provide any information about these important human considerations. The ideal decision-support tool for site selection might include all of these components – likelihood of oyster success, benefits to ecosystem

services and opportunities for community education and funding, and political considerations, such as land ownership and ease of permitting. This might be something to strive for in the future, but for now, as a first step, our project is focusing on needs of and benefits to the Olympia oysters themselves.

End-users were invited to generate additional questions that our new data could answer, but did not do so. They did provide other important questions not related to our project, summarized in Appendix 3. One end-user noted that our questions below tend to focus on negative correlates with oyster success (stressors), and reminded us to also apply our data to positive correlates (food as represented by chlorophyll concentrations, water flow helpful for feeding, etc.). This has been our plan and has been part of our analyses already, but we recognize that we did not communicate this as clearly as we should have, and will do so better in future presentations.

Management decisions about WHERE to do oyster conservation or restoration

This was a major original focus of our grant proposal, and is the area where we have the most data. Note that questions 1-2 pertain to conservation of existing oysters, while question 3 is about restoration/enhancement.

1) Which sites currently support healthy and abundant existing oyster populations that are most likely to be sustainable in the long-term?

Example of management decision: strategic planners and resource agency staff involved in permitting determine which sites/populations need special protection from development or nearby disturbance; regulatory agency considers oyster needs when designating a new marine protected area

Use of our data: data from 18 sites will reveal where oyster densities are highest and stressors are lowest; our laboratory data will shed light on stressor impacts that can be used to characterize sites in terms of suitability

2) Which sites supply a disproportionate amount of larvae to other sites, thereby acting as a source of larvae rather than a sink?

Example of management decision: same as for 1)

Use of our data: data showing source of recruits will reveal which regions supply disproportionate amounts of larvae

3a) *Which sites are best for success and long-term sustainability of oyster restoration projects?*

Examples of management decisions: funder decides between competing projects in different locations; strategic planner for estuarine restoration picks target areas; restoration group decides where to propose next project

Use of our data: can very confidently evaluate the 18 sites we surveyed; can more broadly evaluate site characteristics at sites we didn't survey, if there is some oyster and stressor data available from them; our laboratory experiments will support understanding of stressors that pose greatest threats, and this can be used to identify sites that have low expression of these stressors now and likely into the future

Management decisions about WHETHER to do oyster restoration at a particular site

Our data can productively be used to evaluate likelihood of success at a particular site.

3b) Is an oyster restoration project done at site X likely to be successful?

(This question is very similar to 3a, but in this case applied to a single site as a "yes/no" question about doing restoration, rather than involving prioritization between multiple sites.)

Example of management decision: restoration group decides whether to propose project at a particular site; funder decides whether to fund; conservation land trust or resource management organization decides whether to invest in oyster restoration at a particular property they own

Use of our data: can very confidently evaluate the 18 sites we surveyed; can more broadly develop a tool that evaluates site characteristics and would apply to sites we didn't survey, if there is some oyster and stressor data available from them; our laboratory experiments will support understanding of stressors that pose greatest threats, and this can be used to identify sites that have low expression of these stressors now and likely into the future

Management decisions about WHEN to do oyster restoration

Our data can provide some guidance on seasonal or yearly timing.

4) When should oyster restoration reefs be deployed?

Example of management decision: restoration project planners decide whether to deploy reefs in May vs. July, to maximize oysters and minimize invasive competitors; restoration planners decide whether to avoid or target a predicted El Nino year

Use of our data: we can use our recruitment data to determine which months have oyster recruitment, for which estuarine regions; deploying substrates as late as possible prior to this may minimize occupation of the bare space by competitors prior to oyster settlement. Additionally, our abiotic data (temperature, salinity, etc) can shed light on times of year during which stressful events may be more likely. These data, paired with results from lab experiments, could enable managers to choose less stressful seasons for restoration. This could also be useful if adding oysters to a site is considered. Our data might also shed light on interannual timing (avoid deploying reefs if especially wet winter is projected).

Management decisions about HOW to do oyster restoration

Our data can provide general guidance on oyster restoration approaches. However we can provide no information related to some frequent methodological concerns, such as best type of restoration method (ball, bag, necklace, stake, etc.) to deploy.

5) How do effects of climate-related stressors compare to those of other stressors?

Example of management decision: estuarine ecosystem-based restoration initiative decides which stressors to focus on addressing in their strategic plan, and this decision is influenced by understanding the relative impacts of climate-related stressors vs. other stressors (e.g. focus on reducing hypoxia if effects outshadow those of climate in next decades, but not if they are likely to be overshadowed)

Use of our data: our laboratory experiments are designed to compare (at least qualitatively) effect sizes of climate-related and other stressors; our field data will also shed light on this question through correlative analyses

6) Can resilience of oysters to climate change be enhanced by decreasing other stressors?

Example of management decision: oyster restoration group decides to focus on stressor reduction (such as reducing nutrient run-off or removing a non-native species) at a site instead of (or in addition to) deployment of substrates if there is evidence for greater benefits from this approach; regulatory agencies decide to establish thresholds for stressors (e.g. TMDLs set by water board) because of demonstrated ecological benefits of enhanced climate change resilience as a function of stressor reduction

Use of our data: our laboratory experiments are designed to determine whether there are interactive effects between climate-related and other stressors; our field data will also shed light on this question through correlative analyses; we may be able to detect critical thresholds of certain stressors, such as salinity

7) Do you need to seed oyster restoration substrates prior to deployment in a particular region?

Example of management decision: restoration project planners decide whether natural recruitment is high enough to allow deployment of bare substrates, or whether it is low enough to require "seeding" with spat in laboratory or aquaculture facilities

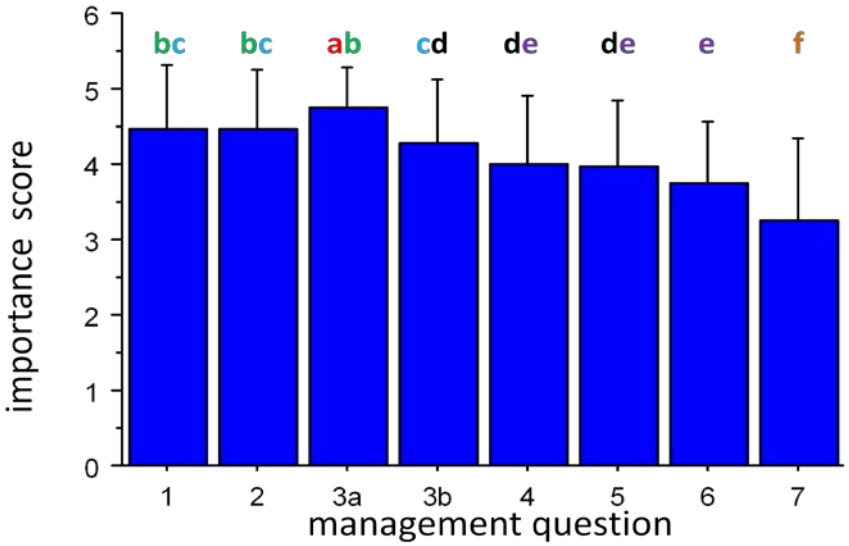
Use of our data: we can use our field recruitment data to determine which sites do vs. don't have adequate recruitment, and use our stressor/site analyses to identify sites with low recruitment that might very effectively support oysters (good conditions, low stressors) if they were seeded onto reefs

Importance of questions to end-users

We asked the end-users "*how important is answering this question for conserving/restoring Olympia oysters in this region*?" They entered a score ranging from 1=not important to 5=extremely important.

All eight of the questions received quite high scores (Fig. 3); none were deemed of low importance for Olympia oyster conservation and restoration. An analysis of the importance scores for all eight questions from the 28 participants revealed some significant differences (ANOVA with question as treatment, $P < 0.001$). (In the figure, questions that are marked with the same color-coded letter are not significantly different from each other in pairwise post-hoc tests.)

Figure 3. Importance scores of management questions.



Question 3a scored the highest, closely followed by questions 1, 2, and 3b. In pairwise post-hoc tests the scores between these four top scoring questions were generally not statistically significantly different (though 3a was significantly greater than 3b). So these four questions should be considered as belonging to one, highest scoring category. Their average score fell between 4, "very important" and 5, "extremely important."

In the next category were questions were 4-6, which were not significantly different from each other in most pairwise post-hoc tests. Their average score was close to 4, "very important."

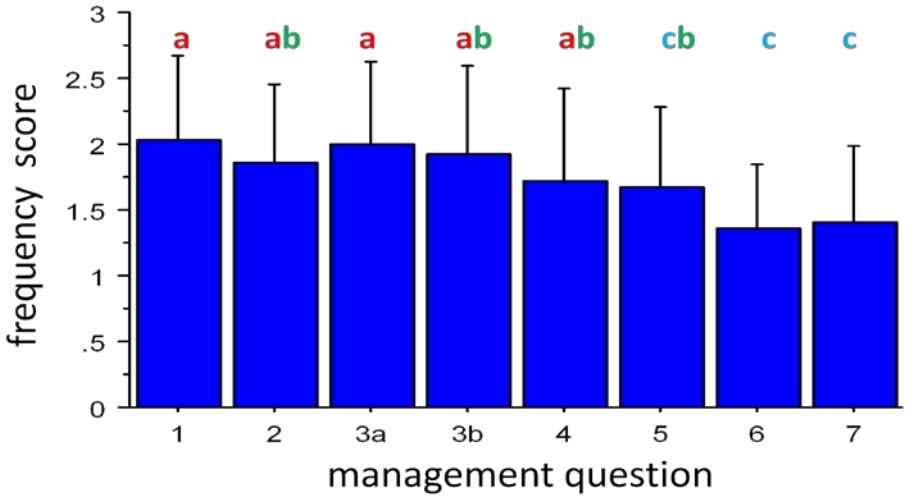
Question 7 falls into its own bottom category, scoring significantly lower than all the other questions, with an average score a bit above 3, "moderately important."

Frequency with which end-users make decisions related to questions

We asked the end-users "*how often do <u>you</u> make decisions related to the above question*?" They entered a score of 1 (never), 2 (sometimes) or 3 (often).

None of the eight questions received an average score close to 3 (often): while these questions were all deemed important, it appears that end-users fairly rarely make decisions related to them (Fig. 4). An analysis of the frequency scores for all eight questions from the 28 participants revealed some significant differences (ANOVA with question as treatment, $P < 0.001$). (In the figure, questions that are marked with the same color-coded letter are not significantly different from each other in pairwise post-hoc tests.)

Figure 4. Frequency scores of management questions.



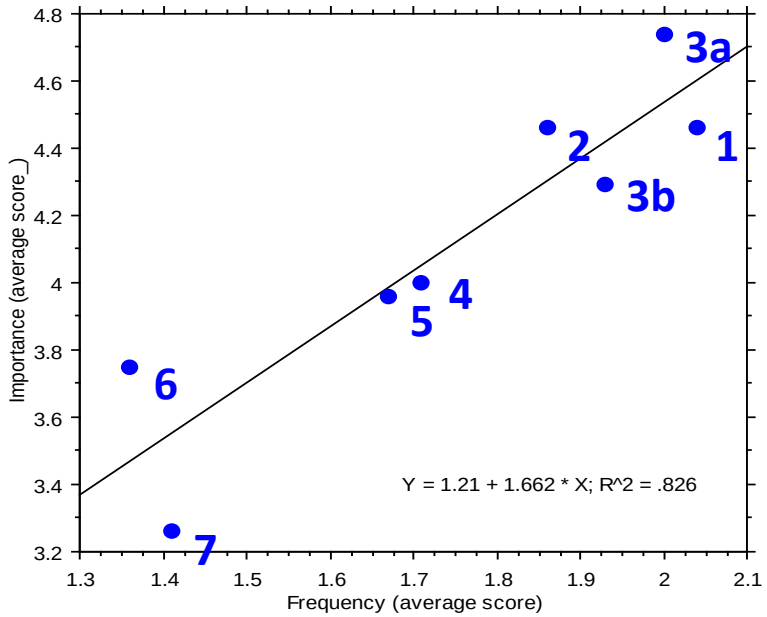
End-users make management decisions related to questions 1 and 3a most frequently, 6 and 7 least frequently, and the other questions at intermediate frequency. These groupings of questions differed statistically from each other in pairwise post-hoc tests.

Prioritization of management questions using importance and frequency

There was a strong relationship between end-user's importance and frequency scores for the questions (regression analysis showed $R^2 = 0.83$, $P = 0.002$), as shown by the graph (Fig. 5) below (questions labeled in blue font). Those questions that scored highest in terms of importance were also the ones, in general, that scored highest in terms of frequency that end-users made decisions involving them. This was not necessarily an expected result; it was perfectly possible that end-users could consider certain management questions to be very important, even though they themselves seldom answer these questions.

This strong relationship facilitates overall ranking of the management questions. Questions 1, 2, and 3 (a & b) clearly emerge as the top scoring questions by both criteria combined.

Figure 5. Relationship between importance and frequency scores.



Adaptation of project to end-user feedback

The formative feedback clearly reveals that the most critical management questions for end-users are questions 1-3a, which focus on WHERE to conserve and restore oysters, and question 3b, which focuses on WHETHER to do so at a particular location. This feedback will ensure that our PI team focuses the majority of its time invested in analysis and product development on addressing these questions. This does not represent a major shift, since questions about site selection and connectivity were a major focus of the original grant proposal that funded this project, and directed the field data collection plan. We will communicate more clearly that positive correlates (such as food, water flow) as well as negative correlates (stressors) are incorporated into our analyses of WHERE / WHETHER questions, as suggested by an end-user comment. We had been somewhat uncertain about whether to continue to pursue the connectivity component of the research, as it is particularly expensive and time-consuming, but the high score received by the question about larval sources indicates the importance of continuing with this work.

Questions 4-6 are of intermediate priority to these end-users. Questions 5 and 6, about effects of climate change stressors – their relative effect and interactions with other anthropogenic stressors – were another major focus of the original grant proposal. Our PI team is committed to answering these questions, in particular through laboratory experiments. However, given the end-user feedback, we will invest less time in translating the findings into management products than we had originally intended. The field of climate change is perhaps still so new that end-users are less sure that there will be concrete management applications from these experiments on climate change stressors. Our results may be useful in pioneering some early efforts to translate climate change research into management guidance, so we will continue to explore this avenue, but given the end-user feedback, we will not invest so heavily in product preparation or

workshop presentations on questions 4-6 as on questions 1-3. However, our research into climate change impacts is also essential to informing site selection (especially questions 1 and 3) and informing sustainable restoration strategies. The laboratory data on responses of oysters to abiotic factors will enable interpretation of field data to assess site value, both in terms of current conditions and future projections.

Question 7 about seeding of reefs was clearly a low priority for end-users, and, given this feedback, we will not invest time in analyses or product development to address this question. It was not part of our original grant proposal, so this does not represent a change in our focus.

TYPES OF PRODUCTS DESIRED AND USED BY END-USERS

Overview of products

Our project team generated a menu of six possible products that could be developed for end-users, to help them to address the management questions prioritized above. These six products are summarized here:

Guidelines

Description: Brief written recommendations, with summary and interpretation of management implications of data, supplemented by figures and tables.

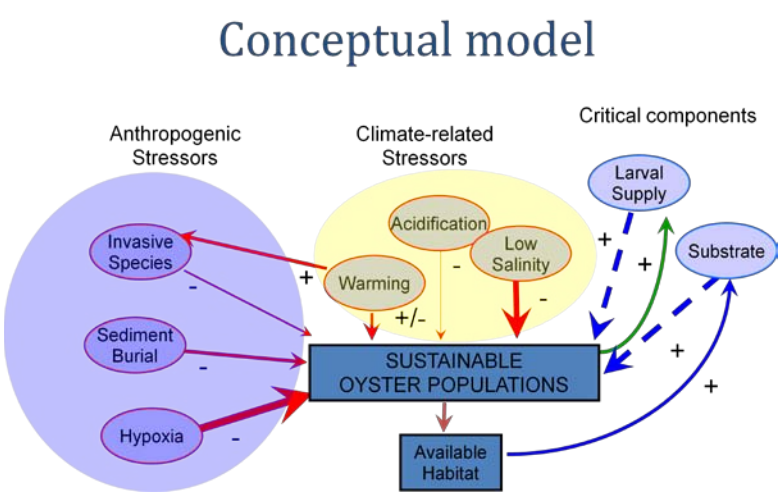
Application to management questions: This product type would be relevant to all of the management questions described above (questions 1-7), containing recommendations about WHERE, WHEN, and HOW to best conserve and restore oysters.

Conceptual models

Description: Diagrammatic synthesis showing which oyster parameters (recruitment, survival, growth) are affected by which stressors and other factors, with different thicknesses of arrows to show relative impacts, and with illustration of interactions between stressors.

Application to management questions: This product could be developed for WHERE questions (for question 1, showing factors relevant for conservation, for question 3, showing factors relevant for restoration). This product could also support some HOW questions, for instance by informing stressor reduction strategies for questions 5-6.

Example:

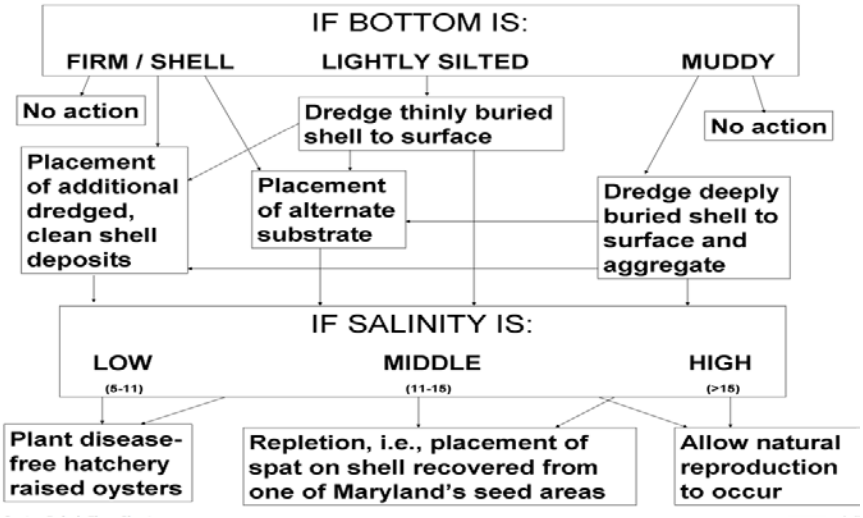


Decision trees

Description: Dichotomous key or flow charts providing guidance about which stressors to focus on at sites with differing conditions.

Application to management questions: This would apply to the HOW questions (5-7), providing guidance on aspects of restoration strategy.

Example: (from Maryland Department of Natural Resources)



Site evaluations

Description: Summary of the 18 monitored sites, based on oyster and stressor data.

Application to management questions: This product would apply to WHERE questions, providing syntheses of attributes relevant for conservation (questions 1-2) and restoration (question 3).

Example: (with fake scores purely for illustration purposes)

SITE	OYSTER RESTORATION SUITABILITY SCORE	OYSTER ATTRIBUTES		STRESSORS			
		Adult density nearby	Recruitment rate	Freshwater exposure	Hypoxia frequency	Sedimentation	Invasive cover
China Camp	High	High	High	Medium	Low	Low	Medium
Port Orient	Low	Low	Low	High	Medium	High	High
Loch Lomond	Medium	Low	Medium	High	Medium	Low	Low
Port Pinole	Medium	Medium	Low	Medium	Low	Medium	Low
Brickyard Cove	Low	Low	Low	High	High	High	High
Sausalito	High	Medium	High	Low	Low	Medium	Low
Berkeley	High	High	Medium	Low	Low	Low	Medium
Arambaru Island	Medium	Medium	Medium	Medium	High	Medium	Low
Oyster Point	Medium	Low	High	Medium	Medium	Medium	Medium
Coyote Point	Low	Low	Low	High	Medium	High	High
Eden Landing	High	High	Medium	Low	Low	Medium	Low

Regional maps

Description: Color-coded maps of the two estuaries with interpolation between our 18 sites, showing general scores (such as the red-yellow-green) in the above chart or individual oyster or stressor attributes. These maps would involve a fair amount of uncertainty (due to interpolation between sampling sites), and would only be suitable for factors that vary continuously (e.g. salinity) rather than discontinuously (e.g. amount of hard substrate at a site).

Application to management questions: This product could be developed for WHERE questions (1-3), and for HOW question 7 (showing which regions of the estuary might require pre-seeding of oysters onto restoration reefs.).

Site selection tools

Description: Formal "decision-support tools" that employ software to create tailored products for end-users. The end-user must input data about a site or multiple sites, and then the tool provides an assessment of the conservation or restoration potential of those sites, using an algorithm and weighting of different types of data.

Application to management questions: This product would be relevant for answering WHERE questions (1 and 3).

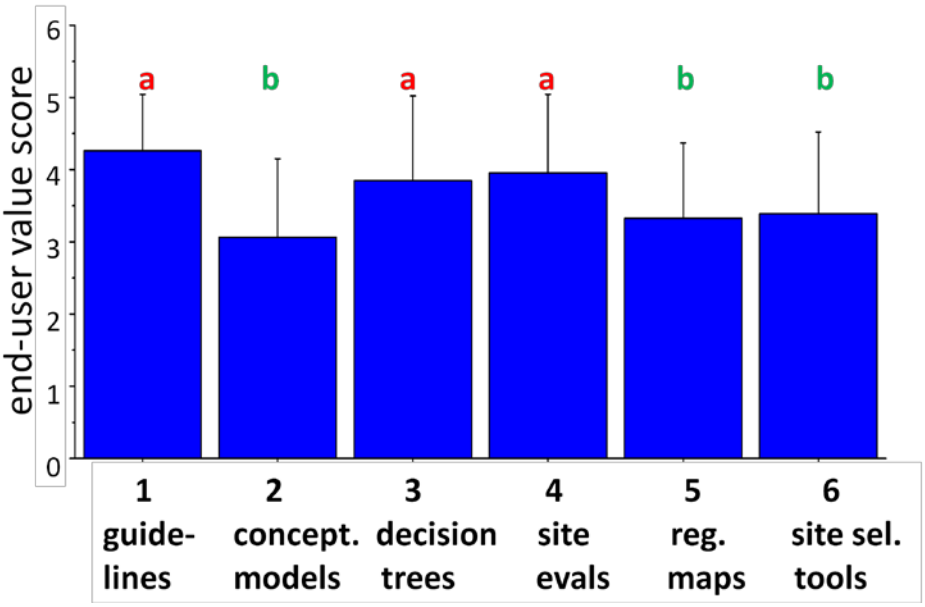
Example: (from Maryland Department of Natural Resources)

Usefulness of products to end-users

We asked the end-users "*based on your past experience with similar products or your anticipated future needs, how valuable would this type of product be for applying new science to your needs*?" They entered a score ranging from 1=not valuable to 5=extremely valuable.

All six products received average scores in the “moderately” to “very” valuable range (Fig. 6). An analysis of the value scores for all six products from the 27 participants revealed some significant differences (ANOVA with question as treatment, P = 0.003). Three products (guidelines, decision-trees, site evaluations) scored significantly higher than the other three products (conceptual models, regional maps, site selection tools.) in pairwise post-hoc tests.

Figure 6. Value of different products to end-users.



Adaptation of project to end-user feedback

End-users significantly favored three products: guidelines, site evaluations, and decision-trees. Since the project team does not have the resources to develop all six of the product options, we will focus on the three products scored as most valuable by the end-users. This represents a modification of our plans as originally outlined in the grant proposal. There, we indicated that we would develop formal decision-support tools to aid in site-selection. However, given the relatively low score received by this type of product, and the very high cost in staff time for development and testing (relative to simpler products such as guidelines and site evaluation tables), we will drop this product from our plans. This decision is also supported by various qualitative comments we recorded from end-users about site-selection tools. Some indicated that they prefer transparent products, such as decision-trees, where all steps are explicit, rather than a “black box” algorithm which is not transparent. Others indicated that site-selection tools are often tedious to use, and require an unrealistic amount of investment by the end-user.

For site evaluation products, one end-user suggested that we include additional types of information relevant for restoration, such as land ownership and access. She also reminded us to include general site information, such as elevation and substrate type. We will attempt to incorporate these types of information in site evaluations, along with the oyster and stressor data we are collecting.

Additional products

In the discussion period following the scoring of products, we solicited additional ideas for products. None of the suggestions were suitable for use with the new data from our team, but we wish to record them here as important needs to be met by future products.

Olympia oyster restoration database
There was strong interest in the room from multiple end-users in the development of an Olympia oyster restoration database that could span the entire coast-wide range of the species. This might be something like a map showing all the different Olympia oyster restoration sites, in an interactive format where you could click on a site and pull up information about who is doing restoration and what they are doing. Ideally, information about restoration methods and outcomes could also be searchable, perhaps in a master table, so you could easily locate all the sites using a similar method.

Olympia oyster monitoring database
There was also interest in a similar database that would document all the sites where monitoring is occurring, again broken down by methods (recruitment vs. adult; natural population vs. restoration reefs, etc.). Providing searchable data (average adult densities, recruitment rates, sizes, etc.) as a part of this would be very useful.

Regional restoration priorities
One end-user advocated for the value of a short strategic plan clearly defining regional restoration opportunities and priorities and the environmental benefits we would get from doing the restoration, perhaps building on the San Francisco Bay Subtidal Goals Report for a broader area.

Human dimensions
Various end-users mentioned that they would like to see development of tools that allow assessment of benefits (in terms of ecosystem services) vs. costs of Olympia oyster restoration.

Historical synthesis
One participant noted that it would be useful to have summarized information on historical distribution and abundance across regions, to help justify and explain restoration targets. (The project PIs may be able to do this in rudimentary form on the project website.)

Living documents
One end-user noted that for any of these products, it would be useful if new information could be added over time by other groups, so the product could be a "living document," continually improved. (The PI team intends the project website to be a platform that allows for continual addition of new information.)

Appendix 1. Participants in April 2013 workshops to provide formative feedback on management applications. Order is alphabetical by affiliation.

Affiliation	First Name	Last Name
BCDC	Sarah	Richmond
BCDC	Bob	Batha
CA Fish and Wildlife	John	Krause
Channel Islands Marine Research Institute	Thomas	McCormick
consultant	Warner	Chabot
CSU Fullerton	Danielle	Zacherl
Elkhorn Slough NERR	Kerstin	Wasson
Elkhorn Slough NERR	Andrea	Woolfolk
Elkhorn Slough NERR	Monique	Fountain
ENVIRON	Bud	Abbott
Hog Island Oyster Company	John	Finger
Isla Arena Consulting	Rena	Obernolte
NERR Science Collaborative	Kalle	Matso
NOAA Coastal Services Center	John	Rozum
NOAA Fisheries	Korie	Schaeffer
NOAA Restoration Center	Natalie	Cosentino-Manning
Puget Sound Restoration Fund	Betsy	Peabody
Richardson Bay Audubon	Laura	Cossette
San Francisco Estuary Partnership	James	Muller
SCC, BAECC, BEHGU, BCDC	Matt	Gerhart
SF Bay NERR	Matt	Ferner
SF Bay NERR	Heidi	Nutters
SF Bay NERR/ SFSU	Anna	Deck
SF Bay NERR/ SFSU	Andy	Chang
SFSU/UCD	Stephanie	Kiriakopolos
State Coastal Conservancy	Megan	Cooper
State Coastal Conservancy	Ariadne	Reynolds
State Coastal Conservancy	Marilyn	Latta
The Watershed Project	Chris	Lim
The Watershed Project	Linda	Hunter
The Watershed Project	Harold	Heidelman
UC Davis	Chela	Zabin
UC Davis	Ted	Grosholz
UC Davis/ Bodega Marine Lab	Brian	Cheng
USGS/ South Bay Salt Ponds Restoration Project	Laura	Valoppi

Appendix 2. Differences in formative feedback by different end-user categories.

We analyzed the responses about management questions and products according to end-user categories. The results of these analyses are summarized below.

Importance of management questions to end-users

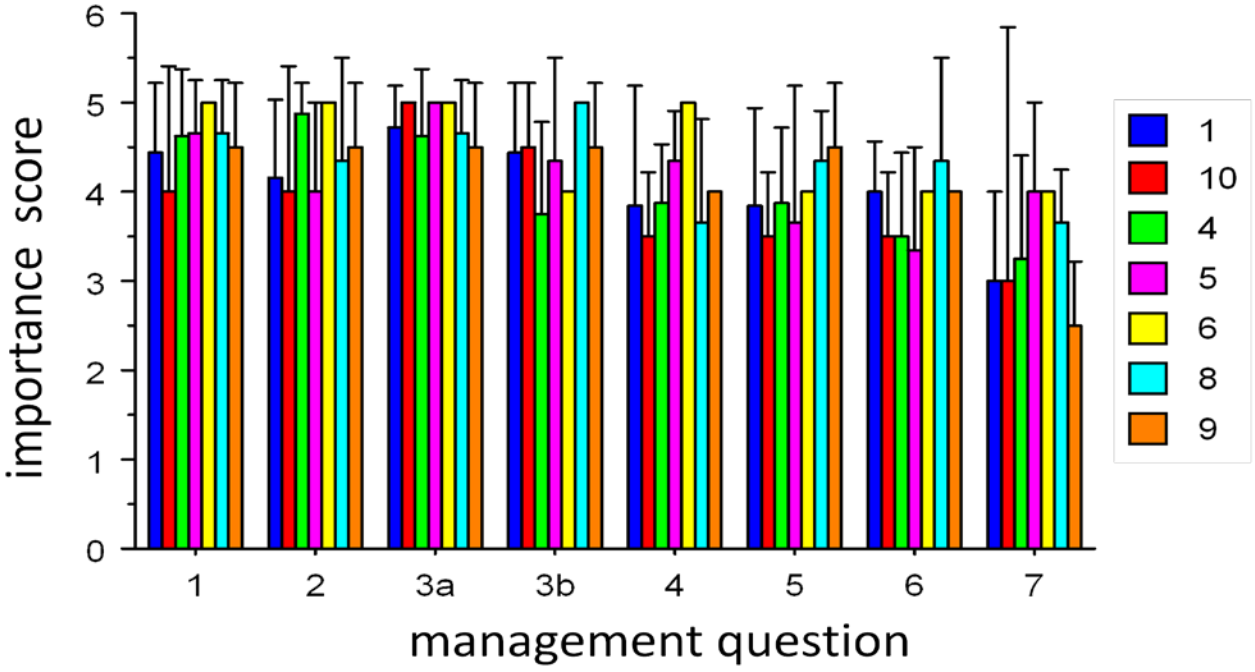
End-user categories differed in terms of which management question they ranked as most important. Table A1 shows the question that received the top score for importance by those end-users categories with sufficient sample size (categories with 1-2 participants had 4-5 way ties between questions, since there were not enough votes to obtain an average with spread between questions). Question 3a was top-scoring for three end-user categories, and question 2 and 3b for one category each.

Table A1. Top-ranked management questions in terms of importance, by different end user categories.

End-user category	# voters	2-sources of larvae	3a-where to restore	3b-whether to restore
1-restoration	**7**		**X**	
4-estuarine planning	**8**	**X**		
5-funding	**3**		**X**	
8-research	**4**			**X**
10-other	**2**		**X**	

Nevertheless, the different categories of end-users scored the importance of the questions quite similarly. An ANOVA conducted with end-user category as factor revealed no significant differences for any of the questions examined separately. Likewise, a two-way ANOVA with question and end-user category (Fig. A1) as factors showed only the former, not the latter, had a significant effect on scores, and there were no significant interactions.

Figure A1. Importance scores of management questions, analyzed by end-user categories.



Frequency with which end-users make decisions related to questions

End-user categories differed in terms of which management question they ranked in terms of frequency with which they address it. Table A2 shows the question that received the top score by those end-users categories with sufficient sample size (categories with 1-2 participants had 3-5 way ties between questions, since there were not enough votes to obtain an average with spread between questions). Question 3a was top-scoring for three end-user categories, question 3b for two, and questions 2 and 5 for one each.

Table A2. Top-ranked management questions in terms of frequency, by different end user categories.

End-user category	# voters	2-sources of larvae	3a-where to restore	3b-whether to restore	5-climate vs. other stressors
1-restoration	**7**		**X (tie)**	**X(tie)**	
4-estuarine planning	**8**	**X**			
5-funding	**3**		**X (tie)**	**X (tie)**	
8-research	**4**		**X**		
10-other	**2**				**X**

The different categories of end-users provided a score for frequency with which they make related decisions that was similar for four of the questions. An ANOVA conducted with end-user category as factor revealed no significant differences in scores for questions 1, 2, 6 and 7. However, there were significant differences for the other four questions, summarized as follows:

3a) *Which sites are best for success and long-term sustainability of oyster restoration projects?*
categories 6 (permitting) and 10 (other) answer these questions less frequently

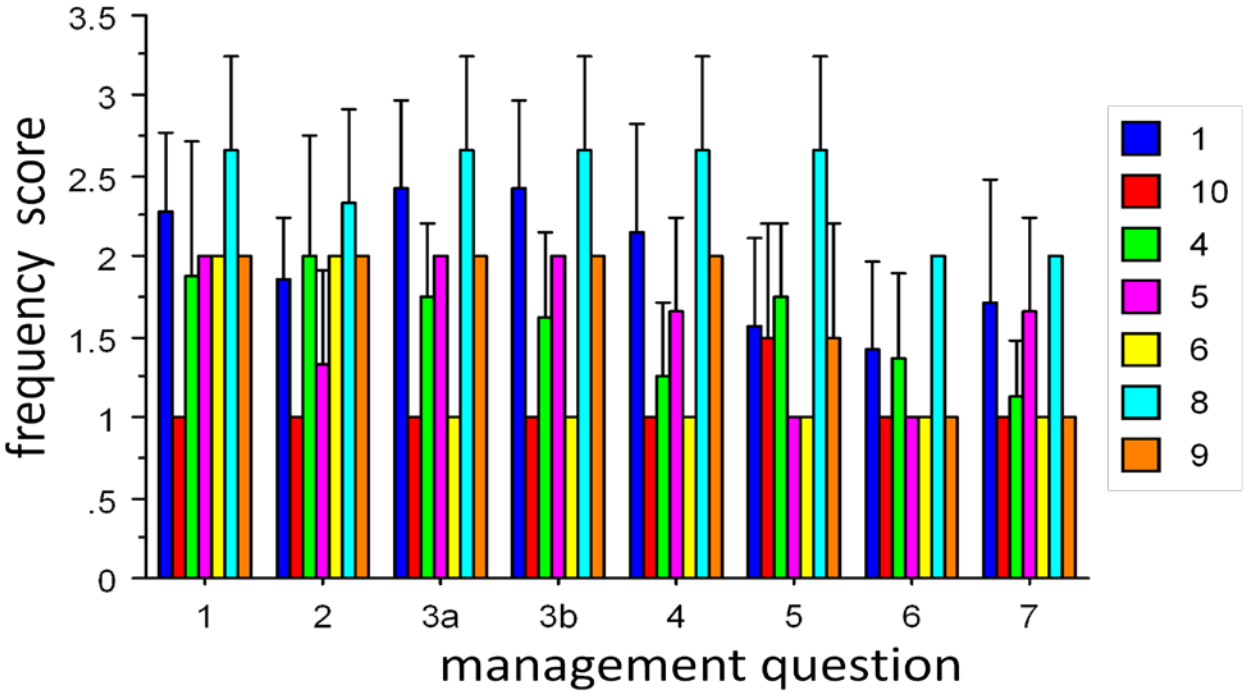
3b) Is an oyster restoration project done at site X likely to be successful?
categories 3 (oyster planning), 6(permitting), and 10 (other) answer these questions less frequently

4) When should oyster restoration reefs be deployed?
categories 3 (oyster planning), 4 (estuarine planning), 6(permitting), and 10 (other) answer these questions less frequently

5) How do effects of climate-related stressors compare to those of other stressors?
categories 5 (funding) and 6 (permitting) answer these questions less frequently

A two-way ANOVA with question and end-user category as factors (Fig. A2) showed a significant effect of both, with no significant interactions.

Figure A2. Importance scores of management questions, analyzed by end-user categories.



Types of products desired and used by end-users

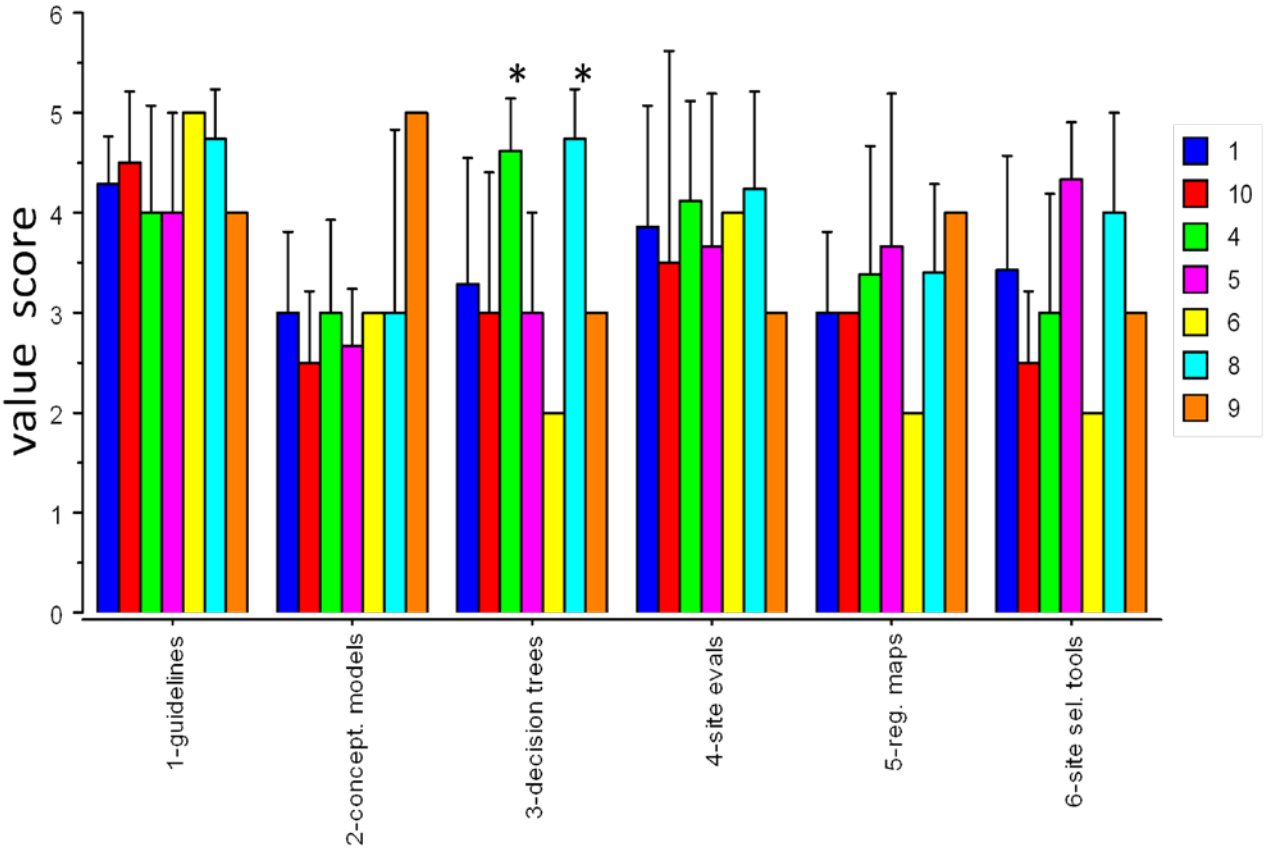
The top-scoring product differed by end-user category. Table A3 shows the product that received the top score by end-users categories. Guidelines were top-scoring for four categories of end-users, decision-trees for two, and conceptual models and site selection tools for one each.

Table A3. Top-ranked products, by different end user categories.

End-user category	# voters	Guidelines	Decision-tree	Conceptual Model	Site selection tools
1-restoration	7	X			
4-estuarine planning	8		X		
5-funding	3				X
6-permitting	1	X			
8-research	4	X (tie)	X (tie)		
9-outreach	1			X	
10-other	2	X			

Nevertheless, the different categories of end-users scored the value of the products quite similarly. An ANOVA conducted with end-user category as factor revealed no significant differences for five of the six products. End-user did have a significant effect on the score of decision trees: end-user category 4 (estuarine planning) and 8 (research) gave a higher score to this product than did other end-user categories. A two-way ANOVA with product and end-user category (Fig A3) as factors showed only the former, not the latter, had a significant effect on scores, and there were no significant interactions.

Figure A3. Value of products, analyzed by end-user category.



Appendix 3. Questions about Olympia oysters.

Participants were asked what burning question they have about Olympia oysters, as an icebreaker to the April 2013 workshop. The questions are listed below, grouped into broad categories. A few additional questions raised during the course of workshop discussions are also included here.

ECOSYSTEM SERVICES

What ecosystem services can Olympia oysters provide?

What ecosystem services can we expect from an oyster restoration project?

How will restoring oyster habitat affect humans?

If we can restore native oyster reefs, how can that mitigate effects of tidal surges (like with Hurricane Sandy)?

How do Olympia oysters taste?

How do oysters contribute to salmon ecology?

SYNTHESIS OF RESTORATION PROJECTS AND OUTCOMES

What oyster restoration projects are happening across the state?

What kind of projects are going on in the Bay Area?

How have restoration projects authorized by BCDC in the Bay area turned out?

Are NOAA-funded restoration projects yielding good returns?

How long should you keep monitoring after a project is completed, and how frequently should you assess?

RESTORATION METHODOLOGY AND RELATED ISSUES

Would this group be excited to see the various agencies coordinate on a streamlined permitting process for oyster restoration?

How quickly do communities in restored sites reach a sustainable stable state?

How can marinas be integrated into oyster restoration projects?

At what scale should we be doing restoration?

What substrates should we use, especially given the decreasing supply of shells? How does substrate choice differ by site (e.g. with wave energy)?

What does field data tell us about which sites would require more maintenance for restoration than others (e.g. sites with heavy sedimentation)?

Is it possible to co-culture eelgrass and native oysters to improve sustainability of project through parallel actions in order to have more lasting benefits?

How do costs of restoration differ at sites that vary in amount of substrate, recruitment levels, etc.? Can you get more bang-for-buck at some sites than others?

How close can development projects be to conservation/restoration areas without having a negative effect? How can we minimize negative effects?

SITE CHARACTERIZATIONS

Is the Sailing Lake population still the largest population in San Francisco Bay?

What are good sites for oyster restoration in San Diego Bay?

What is the extent of the current population in Mugu Lagoon and can we expand it? In light of modification of habitat, will we see resurgence of population? What are the limiting factors?

STRESSORS

What stressors are most important to oysters?

How will estuaries and oysters be affected by acidification?

GENETICS

What is the population structure of Olympia oysters, and how do the population genetics of oysters relate to adaptation to stressors?

Where do the larvae come from?

PHYSIOLOGY

How long can an oyster hold its breath (to avoid stressor)?

If an oyster is "holding its breath," with shell tightly shut for many days, does this result in death of brooded larvae?

RECRUITMENT / LIFE-HISTORY

What happens between the time from when they are released from their mother and when they settle?

Why is Elkhorn Slough so episodic in recruitment?

Why do they settle on substrate we put out but less on existing substrate?

What is the relationship between restoration success and proximity to a source population?

PRE-HISTORICAL BASELINES

How have oysters changed in this region over the last 10,000 years and how is that linked to climate?

Pre-historically, what did oysters live on before there was artificial susbtrate?

SUBTIDAL ECOLOGY

How do oysters interact with other subtidal habitats like eelgrass?

What is going on with subtidal oyster populations? Where are they, how important are they?

OUTREACH / ENGAGEMENT

How can we get more students, volunteers and the public involved in our efforts?

What sites are best for doing demonstrations for the public?