NERRS Science Collaborative Progress Report for the Period 03/01/13 through 08/31/13

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

Principal Investigator(s): Matt Ferner
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Report compiled by: Matt Ferner, Kerstin Wasson and Anna Deck
Contributing team members and their role in the project:

Collaboration Lead:	Marilyn Latta, Project Manager California State Coastal Conservancy Oakland, CA Role on project: Marilyn oversees integration of the applied science with the needs of core local and regional end-users.
Co-Principal Investigators:	Andy Chang, Research Scientist San Francisco Bay National Estuarine Research Reserve Tiburon, CA Role on project: Andy co-leads laboratory experiments, environmental monitoring, oyster surveys and population connectivity studies with a focus on San Francisco Bay sites.
	Ted Grosholz, Professor of Environmental Science and Policy University of California, Davis / Bodega Marine Laboratory Davis, CA Role on project: Ted advises the science team, participates in environmental monitoring and oyster surveys in San Francisco Bay and Elkhorn Slough, and facilitate interactions with end-users.
	Kerstin Wasson, Research Coordinator Elkhorn Slough National Estuarine Research Reserve Watsonville, CA Role on project: Kerstin coordinates and leads development of end-user products resulting from the project. She also assists with field monitoring and overall project management.
	Chela Zabin, Research Scientist University of California, Davis Davis, CA Role on project: Chela co-leads environmental monitoring and oyster surveys with a focus on Elkhorn Slough sites. She also works closely with the Collaboration Lead and regional end-users.
Graduate Investigators:	Jill Bible, Graduate Student University of California, Davis / Bodega Marine Laboratory Bodega Bay, CA Role on project: Jill co-leads laboratory tests of potential stressors on oysters collected from study sites that span a range of environmental conditions in San Francisco Bay.

Brian Cheng, Graduate Student
University of California, Davis / Bodega Marine Laboratory
Bodega Bay, CA
Role on project: Brian co-leads laboratory tests of potential stressors on oysters collected from study sites that span a range of environmental conditions in San Francisco Bay.

Anna Deck, Research Technician
San Francisco Bay National Estuarine Research Reserve
Tiburon, CA
Role on project: Anna co-leads environmental monitoring, oyster surveys and population connectivity studies with a focus on San Francisco Bay sites. She also leads data management and assists with overall project coordination and communication.

A. Progress overview

Project Goal

The overall goal of this project is **to increase the resilience of oyster restoration projects in the face of climate change.** We will do this by developing restoration planning tools or other end-user products that characterize and prioritize sites and source material for restoration projects at two central California estuaries. We will also achieve this goal by synthesizing broader lessons learned about best approaches for enhancing resilience by shellfish in the face of climate change. These end-products will be based on science tailored to address critical information gaps identified by local and regional end-uers. We will quantify stressor levels across sites within and between the two estuaries, determine which climate-related and other anthropogenic stressors have the greatest potential to impact native oysters, investigate how these stressors interact, and characterize oyster population connectivity among the San Francisco Bay sites.

Accomplishments

We adhered to our timeline and moved forward with both the applied science and collaborative components of our project during this reporting period. For the applied science component, we continued surveying oysters and monitoring environmental stressors at all 18 sites across both estuaries, including the final round of intensive annual summer sampling under this project. We completed a three-month laboratory experiment characterizing the threshold sensitivity of adult oysters to low salinity events, prepared a manuscript on the multiple-stressor experiment conducted last year, and continued pilot studies in preparation for another large laboratory experiment this fall that will address a new set of stressor combinations. We summarized the field and lab data collected to date for presentation to end users at a spring workshop and continued our new collaboration with the SF Bay NERR education coordinator and a regional high school to extend data collection and broaden project impacts. For the collaboration component of the project, we completed our mid-project formative feedback phase. We developed a menu of management questions that could be addressed with our new science, and generated a suite of templates for end-products that could be created to translate the science into a useful format for the management applications. We held a workshop and used “clicker” technology to determine the priorities of 28 key end-users engaged in aspects of oyster restoration (ranging from on-the ground implementation to permitting to strategic

planning), with regard to these potential management applications and end-products. The end-users considered management applications regarding site selection and assessment to be top priorities, and considered climate-related issues to be somewhat less important. Our PI team will accordingly invest most heavily in analyses of the data to inform site selection and evaluation, though we will also continue with some of the climate-change resilience analyses originally anticipated, building these into the site assessments. The end-users indicated that products most useful to them were written guidelines, site assessments, and decision-trees. Our PI team will thus invest in preparing these three types of end-products. We will not develop formal decision-support tools as we had originally proposed, since, to our surprise, these were ranked low by end-users. This is an example of the benefit of the NSC model for collaborative decision-making, which allows for flexibility, adjusting project plans midstream in response to end-user feedback.

B. Working with Intended Users

Our collaborative objective for this reporting period was to obtain and integrate formative feedback from end-users on management applications of the new science, and on preferred end-user product formats. We successfully accomplished this objective, and have now completed Phase Two (of three total phases) of our collaborative plan in our original proposal.

Our team invested heavily in this phase. We developed a menu of all potential management questions that could be addressed with the new science from this project. We also generated a suite of potential end-products that could be developed to translate the science into use for these management applications. We developed templates to illustrate the scope and structure of each potential end-product. We then designed an interactive workshop format employing "clickers" (Turning Point Technology) to obtain real-time feedback from end-users, to prioritize our investment in different management applications and products.

Formative feedback from end-users on management questions and products

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 were shared with end-users through our project web-page, working group meetings, and individual meetings with key players.

<u>Management questions</u>

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.

<u>Products</u>

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 for 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).

Presentations to a variety of audiences

In addition to the series of presentations at our interactive workshop, members of our project team made presentations about our project to various audiences during this period. Wasson gave a public seminar about oyster restoration science, with emphasis on this project, to an audience of 100 at UCSC's Seymour Center (public aquarium). Ferner presented on the project to a group of summer interns and new employees at the San Francisco Bay NERR, as well as

to upper-level undergraduates enrolled in summer session courses at the Bodega Marine Laboratory. The education coordinator of the San Francisco Bay NERR continued regular presentations related to the project as part of an emerging high-school environmental science program (described below).

Public website for project

We updated our project website (http://oysters-and-climate.org/) to disseminate the new science and report from our April 2013 workshop. We distributed a brief project update by email to our extensive end-user database and directed them to the webpage for more information.

Linkages to on-the-ground Olympia oyster restoration projects in both estuaries

We actively engaged with on-going Olympia oyster restoration projects during this reporting period, ensuring that we were aware of the key issues and challenges being faced on the ground, so we can include these perspectives in our final products, and so that we can continue to strengthen relationships with key players in local oyster restoration. Chela Zabin, Ted Grosholz and Marilyn Latta are heavily involved in the largest oyster restoration projects to date in San Francisco Bay, a "living shoreline" project just a few miles south of the San Francisco Bay NERR site of China Camp. In Elkhorn Slough, Chela Zabin and Kerstin Wasson are implementing the largest oyster restoration project in this estuary to date, a project funded by California Department of Fish and Wildlife's Environmental Enhancement Fund. Engagement of key staff from our NERRS Science Collaborative project with such field oyster restoration projects will enhance the relevance of project findings for practitioners.

C. Progress on project objectives for this reporting period

Our progress on collaborative objectives of this project is described above. During this reporting period we also made substantial progress on our applied science objectives. Each of those ongoing objectives is listed below with a brief reminder of what we are doing and why, followed by a summary of our recent activities and plans for the next six months. All raw data, analyzed data and associated documents and files are being archived on both Dropbox and a secure data server hosted by San Francisco State University. We are using our online Basecamp workspace to develop and edit documents and to archive discussions among the project team, including outcomes from conference calls and in-person meetings.

Intensively monitor the magnitude and variability of environmental stressors on a spatial scale relevant to restoration projects

We continued measuring the major physical and biological stressors that affect oyster populations at a variety of study sites in both estuaries with a particular emphasis on those stressors expected to be influenced by global climate change. As with site selection, our exact selection of stressors was influenced by early feedback from end-users and includes air temperature, water temperature, pH, salinity, sedimentation, turbidity, chlorophyll *a* (food level), competitive (overgrowth) effects of invasive species, and at some sites dissolved oxygen. In this reporting period we completed our last round of intensive summer sampling including biweekly collection of biological samples for analysis of population connectivty (described below). We also analyzed a large portion of our existing field data and presented those preliminary results at the interactive end-user workshop. A summer intern from Franklin University spent the summer refining methods for processing sediment samples for grain size analysis, advancing our efforts to characterize our field sites. Becuase of unanticipated staff

turnover and reorganization of the research and monitoring program at San Francisco Bay NERR, we were unable to deploy an additional data sonde in the southern portion of San Francisco Bay as planned. Preparation for that deployment was postponed and should commence within the upcoming reporting period. An additional setback resulted from the product recall of our intertidal salinity loggers, manufactured by Onset Computer Corporation. Although monthly averages recorded by the loggers (deployed at three sites in each estuary) are still reliable, there is now unexpected uncertainty in the variability and instantaneous magnitudes of salinity recorded by these loggers. Suitable alternative loggers were researched and we ultimately selected a new logger manufactured by a different company. The recalled loggers have been returned and the new loggers will be ordered in September. Due to large price differences in the Onset loggers and the chosen new loggers, we will only be able to purchase two new loggers to be deployed at the same central and north San Francisco Bay sites where we previously had the Onset loggers. The previously mentioned sonde to be deployed in south San Francisco Bay will replace the Onset salinity logger that was recently removed from that location. In Elkhorn Slough, we will not be able to deploy new loggers and will rely more heavily on the several long term monitoring stations present in the estuary. During the next reporting period we will analyze the combined data to determine what information from the salinity data is appropriate to include in our final analyses and products.

We continued collaborating with a new education program being developed by San Francisco Bay NERR. The Watershed Water-Quality Monitoring Program was pilot tested with environmental science classes at a local high school during in the 2012-2013 school year and will being continued and refined in the upcoming school year. The program uses long-term monitoring of salinity and temperature as a vehicle to teach the scientific method, data analysis techniques, and basic estuarine science and climate change science. As part of the program, the Reserve's Education Coordinator (Sarah Ferner) maintained the education program's salinity loggers at two locations not previously included in our funded project, as well as oyster settling plates at one of those locations. This expanded monitoring of environmental conditions and oyster recruitment is providing an authentic research experience for the students as well as additional data for our oyster project. Unfortunately, as was the case with our primary environmental monitoring, the salinity loggers associated with this educational program also were recalled by the manufacturer. The students participating in this program over the coming school year will focus more strongly on monitoring oyster recruitment and will rely on salinity data collected by the Reserve and other groups instead of collecting their own data in the field.

Test susceptibility of oysters from sites throughout each estuary to environmental stressors representative of current and projected future conditions

Through collaborative interaction with end-users we decided to test oyster susceptibility to two climate change-related factors (temperature and salinity) and two other anthropogenic stressors (sedimentation and hypoxia, both identified by end-users as key concerns for restoration). Our laboratory experiments are testing growth and survival responses of juvenile oysters to several levels of each individual stressor. We identified treatment levels by characterizing the mean and range of stressor variation in each estuary using existing data from San Francisco Bay and Elkhorn Slough NERR monitoring programs and other previous work. For each stressor, we are using levels representing current and projected future conditions driven by climate change. We are testing each factor alone as well as in combination with others, including specifically looking at interactions between climate change-related and other anthropogenic stressors.

The first of these multiple stressor experiments concluded during the last reporting period and was designed to simulate stressors as they occur in the field (high temperature and low

dissolved oxygen in summer, low salinity events in winter), mimicking the timing of these events on different life stages (new recruits in summer and older juveniles in winter). Analyses reveal additive and opposing sub-lethal responses to temperature and hypoxic stress in Olympia oysters. Warming was beneficial for oyster growth, whereas hypoxia resulted in a negative effect on growth. Subsequent low-salinity stress (following a recovery period) did not impose disproportionate effects on oysters previously stressed by the water temperature and dissolved oxygen treatments. A manuscrript summarizing the study is currently in preparation.

The second of these multiple stressor experiments also is designed to simulate stressors as they occur in the field (low salinity events in late winter and spring coupled with or followed by high aerial temperature during daytime low tides). Of particular interest in this experiment will be to test whether the timing of the two stressors (near-simultaneous, sequential, or delayed exposure) affects oyster survival and growth responses. Oyster spawning, larval rearing and settlement of juvenile oysters has been started. Pilot studies to refine stressor levels and treatment logistics will continue for another month in advance of beginning treatment exposures.

In support of both of these investigations, we recently completed a third laboratory experiement to establish thresholds for adult Olympia oysters with respect to low salinity (5 levels) and exposure duration (2 levels). Through these experiments we confirmed that more intense and longer durations of low-salinity events lead to greater mortality and lower food intake during exposure, with population-specific differences in responses. Data analysis is near completion and the writeup of this experiment is beginning.

Link stressor magnitude and variance to Olympia oyster fecundity and demographics

The laboratory work described above will provide us with information about the response of oysters to select environmental stressors, yet field conditions are likely to be significantly more complex, requiring field measurements of oyster demography to link our laboratory results to observed field responses. To better support conservation and restoration efforts, we also need to identify sites to which oysters regularly recruit and/or which support fecund individuals. We therefore are documenting oyster population dynamics through regular surveys of recruitment, growth, survivorship, size distribution, density, and fecundity in the field.

Last year we began developing non-lethal methods to sample brooded larvae from adult oysters in San Francisco Bay, with the hope that we could eventually use this method in Elkhorn Slough where the small oyster population cannot support lethal sampling. During this reporting period, we successfully sampled adult oysters for larvae using a non-lethal method and maintained very low levels of post-sampling mortality throughout the summer. Using this method we found evidence of early stage broods in Elkhorn Slough oysters, but did not find late stage larvae.

Identify source and sink populations and the degree of connectivity between populations in San Francisco Bay

Sites identified as having good environmental conditions for oysters would be of relatively limited use for restoration purposes if oysters do not naturally recruit to those sites. Thus, it is essential to understand the sources and fates of oyster larvae. Larval movement and connectivity within San Francisco Bay is being assessed by comparing shell chemistry of brooded larvae from different sites (collected in fecundity assessments) with the chemistry of recently settled recruits collected during summer (from biweekly recruitment measurements). Data from last summer indicated that there were differences in trace element signatures of broods from different regions of San Francisco Bay. This past summer we successfully

collected enough broods and juveniles during the intensive sampling effort to be able to proceed with the intended analysis. Sample processing will begin in September for those samples.

D. Benefit to NERRS and NOAA

At our recent workshop, we modeled the use of “clickers” (Turning Point Technology) for engaging end-users and obtaining and quantifying real-time feedback. Participants and our PI team found use of this tool to be very effective for scoring options from a menu of management applications and potential tools. The approach used could productively be applied to other NERRS and NOAA initiatives engaging end-users in collaborative decision-making.

The NERRS recently evaluated the pros/cons of using Basecamp for communication. Members of our PI team were able to provide extensive feedback based on their experience with this project. We have found Basecamp to be very useful for 1) rapid group editing of shared documents, where version control is critical, and 2) for reliable archiving and sharing of files and of intellectual development of concepts through electronic communications. However, we note that efficient use of Basecamp requires investment in maintenance and organization by a coordinator, and depends on participants using the program frequently enough to remain familiar with organizational structure and team etiquette about editing procedures. Based on our experience, we recommend Basecamp for a small, active, engaged team, but not for a larger group of occasional participants.

We are continuing to collect a large amount of intertidal and subtidal environmental data that will be shared with the NERRS and various NOAA groups. We expect these efforts to result in a valuable, informative, and often-used dataset filling identified gaps in the region. In particular, our continuous salinity measurements and high-frequency intertidal sampling will yield broadly useful and previously unavailable environmental data. Developing a better understanding of how resource managers and restoration practitioners can benefit from such data should also be of general interest to other NERRS and NOAA efforts around the country.

Finally, we joined a “Transfer” project funded by the NERRS Science Collaborative to extend our project outcomes, methodologies and experiences to oyster farmers, decision makers and scientists in Alaska through a regional stakeholder workshop to be held in March 2014. Ferner and Grosholz will participate in and contribute to that workshop, and graduate students Cheng and/or Bible will travel to Alaska for the workshop and will present on the laboratory experiments and stakeholder engagement strategies employed by our project.

E. Additional updates

During this reporting period, San Francisco Bay NERR underwent a reorganization of their research and monitoring program and staff. Following the resignation of the Reserve’s lead monitoring technician in mid-February, the research technician for our oyster project (Deck) reallocated 50% of her time to lead the Reserve’s System-wide Monitoring Program, and a new research technician (Elena Ceballos) was hired to fill the resulting gap in staff dedicated to the oyster project. Furthermore, the Reserve’s manager (Kooser) resigned in May and a new, interim manager (Mike Vasey) joined the Reserve. Together these changes resulted in more staff dedicating thought and time to the project and, therefore, more capacity for San Francisco Bay NERR to respond to unanticipated increases in future work needs related to the project.