ENVIRONMENTAL ENHANCEMENT GRANT

Pioneering an innovative adaptive management approach to native oyster restoration at Elkhorn Slough

Final Cumulative Report

Overview

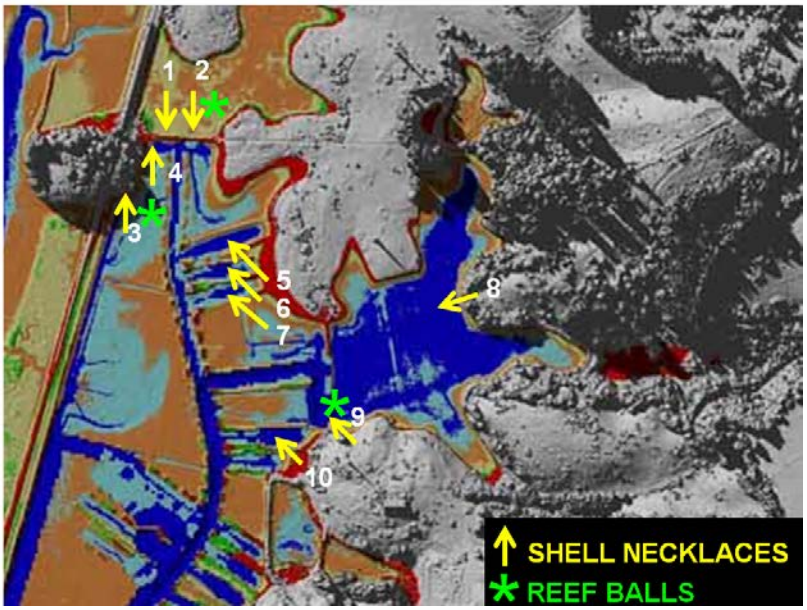
During this period, we continued towards our goal of restoration of the native oyster population of the Parsons Slough wetland complex on the Elkhorn Slough Reserve. Kerstin Wasson, Chela Zabin, Susie Fork, Miguel Rodriguez and numerous volunteers conducted the work. Highlights of this period include:

- We engaged volunteers in constructing and deploying an additional 24 reefs, beyond what we'd originally proposed in the grant application; this brings the total deployed reefs to 164 clam shell reefs, 96 stakes and 27reef balls
- We monitored the difference in sizes of oysters settled in 2012 in low vs. high reefs and discovered that size of oysters was not affected by height, even though low oysters have more submerged time for feeding
- We monitored the effect of moving reefs deployed in 2012 from low to high positions, and found this reduced non-native fouling species cover without having a detrimental effect on oysters, so this appears to be a good adaptive management strategy
- We monitored waterbirds and crabs but detected no effects of the new oyster reefs on them
- We monitored oyster recruitment but unfortunately there was virtually none in 2014 as in 2013; the thousands of oysters that recruited in 2012 are still doing well and the reefs are robust awaiting future recruitment
- We conducted extensive outreach about the project, including completion of a poster presented at ESA and now posted at ESNERR, and powerpoint presentations about the project to a variety of audiences

Our report below details these Task III activities in the context of a cumulative final report on the project.

Site selection

In 2012, our PI team (C Zabin, S Fork, K Wasson) conducted field visits and used GIS layers of bathymetry to select 10 restoration sites within the Parsons complex. We chose sites that were in the same geographic area, to facilitate movement of materials and volunteers among sites. Sites were chosen to have contrasting characteristics to allow for a variety of paired comparisons.



Specifically, we chose pairs of sites

a) With and without full tidal exchange (i.e. comparing 1 & 2 within diked lagoon to sites 3 & 4 on full tidal exchange side of dike)
b) With hard substrate supporting live oysters vs. on mud nearby (i.e. comparing site 1 vs. 2, site 3 vs. 4, and site 9 vs. 10)
c) On mud with nearby hard substrate and oyster vs. on mud far from hard substrates and existing adult oysters (i.e. comparing sites 1, 3 and 10 to sites 5-8)

Volunteer engagement and training

We engaged and trained numerous volunteers in all aspects of this project. In 2012, four volunteers came to a one-time shell-collecting event for a total of 15 person hours. Three volunteers helped deploy the necklaces and reef balls in July, for a total of 15 person hours. Five volunteers also helped with the reef monitoring and bird and crab monitoring for three days in November, December and January for another 30 person hours. In 2013, six summer interns spent approximately 200 person-hours on monitoring and substrate construction, including drilling clam shells, stringing reefs, collecting eucalyptus branches from the Reserve for oyster stakes, and cutting stakes to 4 foot lengths. The interns assisted in pre-recruitment season monitoring, investigating mammal activity near the reefs using camera traps, and deployment of the new necklaces and stakes. Volunteers assisted in December 2013 and July 2014 monitoring for about 10 person hours.

Reef construction

We built and deployed a total of 164 new clam shell "necklaces", 60 in 2012, 80 in 2013 and 24 in 2014. Each contained about 15 large gaper clam shells separated by knots for spacers, with the entire stretch of string containing shells measuring about 1 m.

In 2013, we also constructed oyster stakes from three types of materials: eucalyptus, redwood, and commercial oyster stakes, which are ribbed polyvinylchloride (PVC) poles embedded with calcium carbonate. All stakes were approximately 1" in diameter, and 4' long. The redwood stakes were purchased at a lumber store, eucalyptus was gathered from trees on the Reseve, and the oyster stakes were donated by a commercial oyster grower.Redwood and eucalyptus were selected as natural substrates we expected would hold up well in saltwater and the commercial stakes as a substrate proven to attract oyster recruits.

We also were able to obtain and deploy 27 "reef balls" constructed in Inverness by the Reef Ball Foundation for the San Francisco Bay Living Shorelines restoration project. The reef balls were made with 90% San Francisco Bay derived materials, including pieces of native oyster shell dredged from the bay. Piggy-backing on the Living Shorelines project allowed us to obtain the reef balls at a discount and forgo the usual shipping costs from the Reef Ball Foundation's Florida location.

Oyster recruitment

We conducted thorough monitoring of oyster recruitment on the reefs in December of each year. In December 2012, we detected about 3600 oysters on the 60 new necklaces that had been deployed, a very successful recruitment event. In December 2013 and December 2014, we detected virtually no new recruitment onto the new reefs. This pattern was mirrored in our regular estuary-wide oyster monitoring: 2012 was a great year; 2013-2014 were terrible. This variability in recruitment makes restoration challenging, but at least the 2012 oysters are mostly still faring well in 2014, and the substrates are available and ready for future years of good recruitment.

Reef durability

In general, all 3 types of reefs deployed (necklaces, stakes, reef balls) appear robust three years after deployment. The reef balls are the most durable, but some have sunken partly into the mud due to their height.

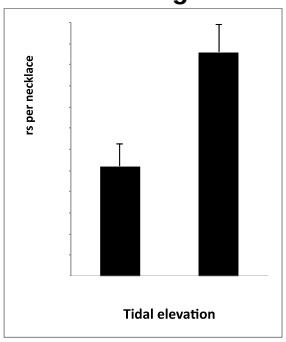
In summer 2013, some shell necklaces were damaged. The necklaces had clam shells broken or completely missing; on six (of sixty) necklaces all 15 original shells were gone. There was no pattern in terms of shell loss between the tidal heights and there was some damage to necklaces at every site except the Whistlestop Lagoon sites (which are in a tidally muted site and thus are never exposed during low tides). The damage had occurred between late May and late June, during which time there were very low minus tides in the predawn hours. As no extreme oceanographic or weather event had occurred during this time period, we suspected that mammalian predator had learned that the oysters growing on the necklaces could be easily obtained by breaking the clam shells. Two of our summer interns set camera traps at two of our sites and recorded raccoons foraging along the rip-rap at night. This seems like the most likely explanation for the damaged necklaces.

We have seen no further damage to the reefs, and will continue to track them and compare long-term durability over the next decade.

Comparison between substrate types

Because recruitment occurred on the 60 necklaces we deployed in July 2012 and not at any point afterwards, we were unable to compare the pros and cons of the three different reef types. We are committed to doing this in the future, after the next good recruitment year.

Effect of tidal height



We found that recruitment of oysters was nearly twice as high in the lower intertidal reefs vs. the higher ones. However, cover by non-native fouling species was higher as well. Thus if a management goal is to maximize oyster numbers, the lower tidal height should be chosen. But if the goal is to maximize dominance by native oysters over non-native species, the higher tidal height should be chosen.

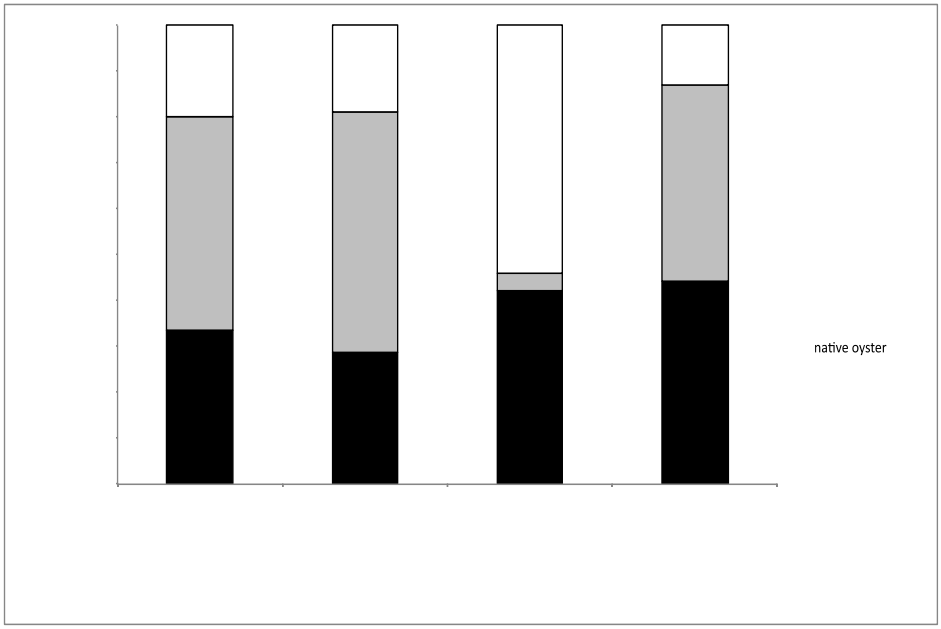
Oyster survival and growth was similar at the two tidal elevations.

Effect of muddiness
We found only slight differences in necklaces deployed in muddy vs. rocky sites. Oysters were somewhat more dominant in the former, perhaps because some of the non-native species have short larval durations and recruit from nearby rocky areas. We had thought that oysters might do much better fouling species in muddy conditions, but the necklaces did not acquire much sediment even in muddy areas, because they hung above the bottom, so we did not thoroughly test this hypothesis.

Effect of distance from established populations
Oyster numbers were similar in areas near vs. far from established oyster and fouling species populations on hard substrates, but fouling cover was lower in the far areas, so the oyster/non-native ratio was improved in these more distant sites.

Adaptive management of elevation of reefs
To test whether cover of non-native species could be reduced without harming oysters, in June 2013 we moved one shell necklace from the low to the high at each of four sites. We counted the number of oysters and quantified percent cover of oysters, other sessile species and bare space on these necklaces before moving them and on a second shell necklace at the lower elevation that wasn't moved and could serve as a control. In June 2014, we measured oysters and non-native sessile species on the necklaces we had moved from the low to high elevations and measured 5-10 of the largest oysters from the 2012 set at both high and low elevations at five sites.

There were no differences in terms of number of live oysters or percent cover of oysters on the necklaces that were moved from the low to the high tidal elevations, compared with controls. However, as predicted, there was a large decrease in cover of other species and an increase in bare space on the necklaces moved to the higher elevation compared with the control necklaces. This suggests that one way to avoid large amounts of cover, particularly the soft, fleshy organisms such as sponges and tunicates that are most likely to limit recruitment space for oysters, is to place restoration structures higher in the intertidal. Given that recruitment was greater at the lower elevation, one possibility for future restoration projects at Elkhorn Slough would be to deploy substrates lower in the intertidal zone initially, and move to the higher zone to reduce cover of other (mostly non-native) cover. There was no difference in size of the largest oysters between high and low tidal elevations, indicating that while oysters in the low intertidal might have an advantage in terms of longer feeding times and less stressful conditions, over the long term, oysters appear to do just as well at the high vs. low elevation in attaining large size.



Waterbird and crab/benthic fish monitoring

We continued our regular monthly waterbird monitoring at permanent long-term monitoring sites near the oyster restoration reefs and detected no significant effects on waterbirds. We also conducted our annual minnow trapping for crabs and benthic fish at nearby sites and detected no clear changes. Both of these monitoring time series are extremely noisy, so we have not yet been able to detect any effects of the reefs.

We also began targeted surveying of both crabs and waterbirds directly at 5 of our project sites. Both types of monitoring compare abundances and diversity in shorelines plots that contain our restoration structures and adjacent control plots of the same size and shoreline height and structure.

Crab trapping was done in fall and again in late spring over the course of two days using pitfall traps to capture small crabs and large and small minnow traps for medium and large crabs. Crab abundance was similar in plots with our structures and nearby control sites

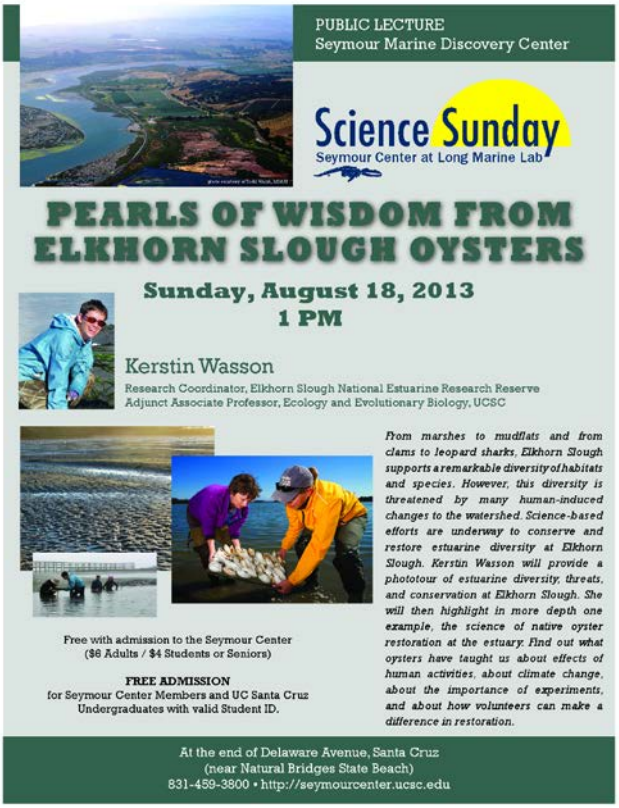
Targeted waterbird monitoring by staff and volunteers (monthly surveys January to April) did not yield significant differences in bird abundance between reef vs. adjacent mudflat control areas. Because these areas are small, most frequently there are zero birds in both reef and control.

Thus, overall, we have detected no effect, yet, on birds or crabs, of deploying the reefs.

Public outreach

We have conducted extensive public outreach about the EEF-funded Olympia oyster restoration project at Elkhorn Slough.

- We were interviewed by Krista Almanzan, News Director for KAZU, the local NPR station, and a brief story on the project ran during All Things Considered on 11 May 2012, when we were still in the planning stages of the grant-funded work – see http://kazu.org/post/saving-californias-native-oyster
- Our project was described in the 3 August 2012 newsletter of NOAA's Office of Coastal Research and Management (OCRM) – see attachment at end of this file.
- We described the oyster restoration project to an audience of 100 community members at a Sunday Science series at UCSC's Seymour Marine Discovery Center, in a talk entitled "Pearls of Wisdom from Elkhorn Slough oysters", in August 2013.
- We wrote an article for the Elkhorn Slough Reserve volunteer newsletter, which is sent to a few hundred local community members, in both September 2012 and December 2013.
- We updated the oyster research web page and downloadable Powerpoint file on the Reserve's website: http://www.elkhornslough.org/research/conserv_oysters.htm
- The oyster restoration work was featured in



February 2013 on the Smithsonian Environmental Research Center's Marine Invasions Research Laboratory website, which highlights work done by members of this research group: http://www.serc.si.edu/labs/marine_invasions/feature_story/February_2013.aspx

- We gave a brief talk on the project at the San Francisco Bay Native Oyster Working Group meeting in October 2012
- We highlighted the research in powerpoint presentations in July 2012 for Dr. David Kennedy, NOAA's chief operating officer, and in February 2013 for Dr. Amber Pairis, Climate Change Advisor to the Director of the California Department of Fish and Wildlife
- We presented a poster on this work at the Ecological Society of America annual meeting in Sacramento on August 15 2014 and at the California Estuarine Research Society meeting at Bodega Marine Laboratory, September 26-28; he abstract for the ESA poster is available at http://eco.confex.com/eco/2014/webprogram/start.html
- We presented the findings of the project at an invited seminar at UC Davis' Bodega Marine Laboratory in October 2014
- We have prepared a draft manuscript, which we plan to submit to Restoration Ecology in early 2015
- We submitted an abstract for a talk on this project in a special Olympia oyster session at the National Shellfisheries Association meeting in Monterey, March 2015