

Elkhorn Slough National Estuarine Research Reserve

Research Questions

The following are the major questions that ESNERR scientists (and collaborators) are currently addressing through long-term monitoring and short-term applied research. These represent questions whose answers are critically needed for improving Elkhorn Slough area conservation, and which lend themselves to the expertise and resources of ESNERR.

1) ESTUARINE HABITATS

Hester Marsh Restoration Questions

ESNERR recently completed a 50 acre project restoring high marsh, tidal creeks, and coastal grasslands. The marsh was restored by adding soil to raise the elevation of an area that had subsided as a result of past diking. Together with student collaborators, ESNERR has intensive monitoring and restoration experiments at this site. A second phase to restore an additional 50 acres will be initiated soon.

How is elevation changing over time at the restoration site?

Background: Added sediments and the underlying sediments may compact or subside over time. The higher the elevation, the longer the marsh will be resilient to sea-level rise.

Approach: Create digital elevation model using unmanned aerial vehicles coupled with ground control points; measure elevation at permanent transects using laser level; measure fine-scale changes using surface elevation tables. Repeat all of above at least annually.

Who: Endris, Haskins, Woolfolk, Fountain (and I. Aiello)

What are spatial and temporal patterns of marsh colonization at the restoration site?

Background: Following construction, the marsh landscape was bare. The speed and patterns of colonization are of interest.

Approach: Use aerial imagery and permanent field transects to document changes in cover and species composition over time. Correlate these to spatial factors (distance from creek, elevation, etc.) and temporal factors (rainfall, seasonality, etc.).

Who: (A. Thomsen, K. Tanner) Wasson, Woolfolk, Endris, Haskins, Fountain, Fork, Jeppesen

What factors enhance success of high marsh plantings?

Background: To ensure representation of rarer marsh plants (in addition to the dominant pickleweed), ESNERR planted about 20,000 high marsh plants, each as a part of various experiments.

Approach: Conduct replicated experiments to examine the effects of clustering (positive interactions/facilitation in tight groups vs. uniformly spaced plants), biochar, patch size (small or large patches of plantings), and different marsh species (which initially succeed and which persist in long-term)

Who: Wasson, Woolfolk, Olsen, Paul, Fountain, Jeppesen, Fork (with K. Tanner, A. Thomsen, E. Watson, B. Wilburn)

What are patterns of crab colonization and how do crabs affect new marsh plants?

Background: Crab densities are high in many parts of the estuary, but it is unclear how rapidly they colonize restoration sites and what effects they may have.

Approach: Monitor colonization patterns over space and time. Conduct replicated experiments to examine crab effects through fence exclusions.

Who: (K. Beheshti, B. Silliman) Wasson

What is the significance of restoration for greenhouse gas dynamics?

Background: Marshes sequester lots of carbon, and so converting mudflat and grassland to marsh should capture significant new amounts of carbon dioxide, and ideally not emit significant levels of other greenhouse gases.

Approach: Monitor carbon sequestration and gas emissions at the restoration site before and after restoration, as well as at control sites (degraded, unrestored marshes) and reference sites (intact high marshes).

Who: (E. Watson, C. Wigand) Fountain, Wasson, Woolfolk, Fork, Jeppesen, Endris, Haskins

What are patterns of animal use at the restoration site?

Background: While the primary goal of the project was to restore marsh vegetation, a secondary goal is to support associated animal communities.

Approach: Monitor animal use of the restoration site, when possible using BACI approach (before vs. after, control vs. restoration site). Sampling efforts include fishes, waterbirds and marine mammals, and may expand to include invertebrates.

Who: Fountain, Jeppesen, Fork, Parkin, Eby

What are water quality consequences of restoration?

Background: The site formerly was dominated by shallow mudflats prone to algal mats and nighttime hypoxia. Raising the elevation to support marshes and limiting flooded areas mostly to channels should improve oxygen conditions.

Approach: Monitor water entering and exiting the site with an in-situ sonde.

Who: Jeppesen, Haskins

Other Wetland Habitat Questions

Can thin-layer sediment placement (TLP) enhance high marsh plant communities and reduce bare ground in drowning low marshes?

Background: TLP is one of the only tools to help support marshes in place in the face of accelerated relative sea-level rise. It has not been broadly tested in contrasting geographies and plant communities.

Approach: Conduct experiment TLP in high and low marsh communities at Elkhorn Slough and seven other National Estuarine Research Reserves and analyze outcomes.

Who: (K. Raposa) Woolfolk, Fountain, Endris, Wasson (and others)

How is extent and distribution of wetland habitats changing over time?

Background: We have detected major changes in the distribution and abundance of estuarine habitat types over the past century. We continue to follow changes to inform restoration and management strategies.

Approach: Monitor changes to extent of different intertidal estuarine habitat types with aerial imagery, and broad intertidal elevation with LiDAR.

Who: Endris

What were historical conditions of estuarine wetlands at Elkhorn Slough?

Background: Human activities have greatly changed the extent and conditions of estuarine habitats at Elkhorn Slough. Better understanding of baselines can guide restoration targets and inform feasibility.

Approach: Synthesize historical documents and maps to characterize historical conditions.

Who: Woolfolk

What are the major causes of salt marsh degradation in undiked areas?

Background: There has been extensive dieback of salt marsh in some Slough regions in recent decades, while other regions have been quite stable. Understanding the causes of marsh loss will help us to better conserve and restore it.

Approach: Characterize drivers of marsh stability vs. health, including sediment deposition rates, marsh plain elevation, and tidal inundation patterns to better understand patterns and mechanisms of marsh loss. Examine role of below-ground decomposition. Correlate periods of high loss with local oceanographic/atmospheric conditions, in particular those affecting water levels.

Who: Endris, Woolfolk, Wasson, Jeppesen, Fountain, Beheshti, Byrd

Are Slough mudflats and banks undergoing deposition or erosion?

Background: Subtidal habitats in the estuary have been shown to be eroding rapidly in the lower estuary. What is happening in intertidal habitats, and how does this vary by Slough region?

Approach: Terrestrial laser scanning provides detailed analysis of changes in topography at long-term monitoring sites. These results can be compared to more crude measures from field bank erosion measurements or analysis of aerial photographs.

Who: Endris (with I. Aiello)

How is the boundary between estuarine wetlands and uplands migrating over time?

Background: The marsh-upland ecotone harbors the greatest diversity of native marsh plants, yet is potentially very susceptible to human disturbances from the upland as well as from changes to tidal hydrology.

Approach: Track changes in ecotone width and location over time, and correlate changes to inundation frequency.

Who: Wasson, Woolfolk

How does herbivory affect marsh restoration?

Background: Intensive herbivory on newly planted marsh species has been observed at some sites with high rabbit numbers. How typical is this, and can it be avoided?

Approach: Conduct experiments comparing survival and growth caged vs. uncaged marsh plants, and test various anti-herbivory strategies, including reducing forb cover used as refuge for rabbits, and attempting to frighten rabbits with recordings of predators.

Who: (K. Tanner, J. Suraci) Wasson

Water quality questions

What are the spatial and temporal dynamics of estuarine water quality and weather?

Background: Water quality is considered one of the best indicators of estuarine ecosystem health. We want to detect long-term changes over time, short-term changes related to diurnal effects, tides, and weather, and spatial patterns.

Approach: Conduct continuous in-situ monitoring of water quality at four stations in Elkhorn Slough, collect weather data at one of these, and nutrient data monthly at these four stations. Sample water quality and nutrients monthly at four stations in the Elkhorn Slough area. Synthesize these data into annual water quality report cards. Analyze data to determine factors that predict low oxygen events.

Who: Haskins, Jeppesen (with G. Lessa)

What are sources of nutrient loading to the estuary?

Background: High nitrate concentrations are measured in the South Moss Landing Harbor at the Potrero tide gates. But which tributaries contribute the most to these loads and concentrations? And how are these sources changing over time? Are management changes resulting in water quality improvement?

Approach: Deploy ADCPs to measure flow and use these data along with nutrient data to model nutrient sources and loading.

Who: Haskins

How can hypoxia be reduced in managed wetlands?

Background: Some wetlands managed by ESNERR and ESF must remain behind water control structures. These areas typically experience frequent low oxygen conditions.

Approach: Adaptive management experiments, monitoring water quality in response to manipulations of water control structures or deployment of additional structures to direct flow.

Who: Haskins (and other staff and volunteers)

Oyster Questions

What conditions favor native oysters in Elkhorn Slough?

Background: Native oysters increase biodiversity and water quality, but have declined precipitously at most Pacific estuaries. Oysters show great spatial and temporal variability in abundance.

Approach: Conduct correlative field studies and small-scale restoration experiments to determine the factors that favor native oysters vs. non-native fouling invertebrates in Slough habitats.

Who: Wasson, Fork (with C. Zabin)

Can small-scale restoration aquaculture enhance Elkhorn Slough native oyster populations?

Background: Native oysters rarely reproduce successfully in Elkhorn Slough. They have become so rare that they may disappear entirely from the estuary.

Approach: Raise oysters from native, local broodstock and deploy them to the field to enhance local populations, and monitor outcomes.

Who: Wasson, Fork (with L. Gardner, D. Gossard, B. Hughes, C. Zabin)

What lessons have been learned from Olympia oyster restoration up and down the coast?

Background: For the past few decades, small-scale oyster restoration projects have taken place, from southern California to British Columbia.

Approach: Synthesize information from all past native oyster restoration projects on this coast, highlight lessons learned and recommend improvements.

Who: Ridlon, Wasson (with C. Zabin, B. Peabody, E. Grosholz, D. Zacherl and others)

What are the potential risks and rewards of conservation aquaculture for Olympia oysters and other reef-building species?

Background: For valued native species with limited reproduction, conservation aquaculture may provide a valuable boost to local populations.

Approach: Provide guidance, for Olympia oysters in particular and reef-building species in general, on priority locations and conditions for using aquaculture as a tool to support populations, with separate consideration of small-scale aquaculture for restoration vs. larger-scale commercial aquaculture.

Who: Ridlon, Wasson (with E. Grosholz, T. Waters and others)

Questions about Animals in the Estuary

How sensitive are different estuarine animal species to climate change?

Background: With 10+ years of monitoring data for multiple indicators, we can determine how much interannual variation in responses is driven by changes in climatic variables such as temperature and rainfall. Indicators that are responsive to interannual differences in weather will be sensitive to predicted climate change.

Approach: Correlate abundance of estuarine organisms and conditions of estuarine habitats from long-term monitoring programs to weather data.

Who: Wasson, Fork, Haskins, Jeppesen, Endris

What are spatial and temporal trends of waterbird use of Elkhorn Slough area habitats?

Background: Wetlands provide key habitat for migratory shorebirds and other waterbirds. We want to better understand spatial variation in habitat use within the Slough and between the Slough and other wetlands in the region, and we want to detect any marked declines in any species in order to mobilize further research into geographical scope and possible causes of the decline.

Approach: We carry out Slough-wide monitoring of waterbirds twice during fall and twice during spring migration, and will compare our findings to those of Morro Bay and eventually other regional estuaries.

Who: Fork, Endris, Fountain, Murphy (and many volunteers)

How is habitat use by breeding egrets, herons, and cormorants changing over time?

Background: We are interested in tracking the numbers of nesting birds over time, as well as changes to their reproductive timing. We also want to detect any major breeding failures.

Approach: Monitor nesting numbers, reproductive success.

Who: Wasson, Fork, Murphy (and other volunteers)

How are mudflat communities near the mouth changing over time?

Background: The mudflats near the Elkhorn Slough mouth are potentially affected by numerous anthropogenic alterations (tidal erosion, power plant intake, harvesting, pollution). We want to be able to detect declines in abundance of key species.

Approach: Annually monitor permanent transects at four sites near the mouth (and one on the Reserve) for large clams, worms, eelgrass, and macroalgal cover.

Who: Fork, Wasson, Jeppesen (with volunteers)

How are crab communities in the estuary changing over time?

Background: The European green crab invaded Elkhorn Slough in 1994. We are interested in potential effects of this species on native crab. We also wish to detect new crab invasions (e.g., Mitten Crab), ideally early enough to allow for eradication.

Approach: Annually monitor crab abundance using minnow traps at two permanent sites in the Slough.

Who: Fork, Jeppesen

How are estuarine snail populations changing over time at Elkhorn Slough?

Background: We are particularly interested in three sometimes very abundant snail species, *Batillaria attramentaria*, an invasive mudsnail that was once phenomenally abundant but has declined dramatically at many sites recently; *Tryonia imitator*, a threatened brackish snail with poorly understood distribution in the area which has gone locally extinct in some marshes; *Melampus californica*, a southern species that has recently established in the estuary.

Approach: Track distribution and abundance of snail populations over time and space in Elkhorn Slough, and correlate patterns to potential physical and biological factors.

Who: Fork, Wasson, Jeppesen (and J. Byers, M. Kellog, and others)

Are sea otters controlling green crab populations at Elkhorn Slough?

Background: The European green crab invaded Elkhorn Slough in 1994, about when otters were starting to more heavily colonize the estuary. Green crab populations have never really taken off, and this could be due to otter predation.

Approach: Correlate green crab to otter densities over space and time at Elkhorn Slough, and compare demographic trends in green crabs at Elkhorn to those at other estuaries without otters.

Who: Jeppesen, Wasson, Eby (with B. Hughes, T. Tinker, C. de Rivera, E. Grosholz)

How do sea otter abundance patterns change over multiple temporal scales?

Background: Otter abundance in Elkhorn Slough varies at multiple scales, including diurnal, tidal, seasonal, and inter-annual.

Approach: Track distribution, abundance, behaviors of otters in the Slough over time and space, and analyze results.

Who: Eby, Scoles, Wasson (with T. Tinker, M. Staedler, J. Tomoleoni and others)

How do mammals use the ecotone between salt marshes and adjacent uplands?

Background: Wildlife trails and sightings are common at the landward edge of salt marshes, but little is known about animal use of this zone.

Approach: Camera trap wildlife in the marsh-upland ecotone (vs. the marsh below and the upland above), to characterize how this zone is used. Deploy fence exclosures to test whether animal trails affect plant communities. Characterize raccoon foraging on crabs and how it varies with marsh structure.

Who: Wasson, Woolfolk

2) FRESHWATER AND RIPARIAN HABITATS

What restoration strategies can support a habitat corridor for Santa Cruz Long-toed Salamanders in the eastern Elkhorn Slough watershed?

Background: Federally endangered Santa Cruz Long-toed Salamanders have a highly restricted range, breeding in only a few wetlands in the eastern Elkhorn watershed. Enhancement of these wetlands and restoration or creation of other wetlands and terrestrial habitats between them can support these endangered populations and facilitate dispersal between them.

Approach: Work with regional partners in land management and conservation to design, implement and monitor restoration of freshwater habitat and habitat enhancement strategies in this corridor.

Who: Fork, Wasson, Woolfolk, Curthoys, Feliz, Endris (with K. Collins, D. Dunkell, M. Silberstein, C. Mitcham, K. Camara, and others)

How are patterns of amphibian and reptile usage of Reserve ponds changing over time?

Background: To inform management of Reserve ponds, we want to understand temporal and spatial trends in species usage in wetland habitats.

Approach: Monitor amphibians and reptiles using visual encounter surveys and surveys for egg masses and larvae.

Who: Fork, Feliz (and volunteers)

Can eDNA be used to detect rare amphibian breeding sites in central California?

Background: Field surveys can miss amphibians present at very low abundance levels. Environmental DNA may offer a complementary method of detecting amphibians, which can inform management strategies.

Approach: Test eDNA assays for rare amphibians in central California, recommend protocols, and ideally identify new breeding sites.

Who: Wasson, Fork, Laursen, Feliz (and C. Goldberg, C. Mitcham, C. Wyckhoff, and others)

3) COASTAL PRAIRIE

What strategies are most effective for restoring native prairie assemblages at the Hester Restoration site?

Background: Following construction, Hester's uplands fringing the marsh were largely bare. This presented an opportunity to restore native grassland communities.

Approach: Restore native grasses and forbs using different methods (hand-seeding vs. plugs, etc.) in different places, and track outcomes

Who: Woolfolk, Olsen, Paul, Fortner, Curthoys, Osborne (and volunteers)

What strategies are most effective for enhancing native prairie assemblages on the Reserve?

Background: The Reserve grasslands are highly invaded due to changes in disturbance regimes, introduction of invasive species, and earlier agricultural management of the lands. We wish to better understand the consequences for a variety of conservation targets (native grasses, annual forbs, perennial forbs) of differing management strategies.

Approach: Restoration experiments examining effects of strategies such as planting, mowing, and grazing on different indicators. Monitor effects of a recent prairie fire.

Who: Woolfolk

4) COAST LIVE OAK

What are the costs and benefits of pocket understory restoration projects?

Background: Volunteers “adopted” small areas of oak woodland, removing non-native species and planting natives.

Approach: Assess the value of these small-scale citizen-restoration projects to the participants themselves as well as to wildlife use and to native plant abundance and diversity both within and adjacent to the pocket restoration sites.

Who: Fork, Woolfolk, Wasson (and B. Candiloro and volunteers)

What are the long-term trends in cavity nesters?

Background: As an indication of oak woodland health, we are interested in cavity nesting birds. Long-term trends might result from climate change (earlier breeding), sudden oak death epidemic (low breeding success), etc.

Approach: Monitor 150 nestboxes in oak woodlands to determine which species occupy them, fledging success, parasitism, and timing of reproduction.

Who: Fork, Murphy (with other volunteers)

There is also another document available from the research homepage of www.elkhornslough.org that lists high priority questions suitable for students and other researchers to address – those are the questions we’re not tackling, but hope someone does!