

Elkhorn Slough Research Project Ideas

The following are some of the many possible questions student researchers are encouraged to attempt to answer at Elkhorn Slough. Some are well-suited to short-term projects, others would require longer efforts, such as graduate thesis research.

We at the Elkhorn Slough National Estuarine Research Reserve particularly encourage projects that examine threats to Slough ecosystems and how best to minimize them. The questions below are organized first by habitat type, then mostly by threats to each. While these questions represent priorities for informing conservation, we're curious and interested in all aspects of the Slough. Feel free to contact Kerstin Wasson (kerstin.wasson@gmail.com) for advice about a project at the Slough. If you would like to conduct research on the Elkhorn Slough Reserve (northeast portion of Slough), you will also need to contact her to apply for a research permit.

1) ESTUARINE HABITATS

RESTORATION

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. A second phase to restore an additional 50 acres will be initiated soon. We welcome student projects investigating any aspect, physical or biological, of restoration at this site. Below are a few examples, but feel free to propose something different.

What factors enhance pickleweed colonization at Hester marsh restoration site?

Pickleweed colonization has been very uneven. A correlative analysis could identify soil and landscape factors related to colonization. Moreover, experiments could be conducted to test factors that might affect seed retention (microtopography, algal wrack, etc.) or to compare germination and growth under different conditions.

How does seed supply vary across the restored Hester site?

Related to the question above, to better understand the patterns of pickleweed colonization. Where is seed deposition greatest? Do king tides wash seeds off the lower and mid elevation areas of the marsh plain and deposit them at higher elevations? This could inform whether and where seed retention strategies (mentioned above) are needed.

What is the role of herbivory in affecting plant restoration success?

In areas with adjacent cover (stands of tall forbs, etc.), there are dense populations of brush rabbits and other herbivores, that could negatively affect marsh restoration. Canada geese also frequent the marsh and consume plants. Conduct a caging or exclusion experiment to quantify these effects.

Is there additional utility of unmanned aircraft systems (UAS) data for monitoring restoration beyond our current uses (elevation, overall vegetation cover)?

Can we use UAS data to estimate biomass and ecosystem services related to biomass, like carbon sequestration? Can we find a way to separate out vegetation cover of different marsh species in

UAS imagery, e.g. pickleweed and *Spergularia*, maybe by using near infrared/red edge data or timing data acquisition to take advantage of phenological changes like flowering?

Benthic flux before/after (oxygen demand, nutrient flux, etc.)

Residence time in back areas of phase 1

How is the fish or invertebrate community changing over time at the restoration site, and how does it compare to other marshes in the estuary?

Very little is known about salt marsh habitat use by fish and invertebrates in Elkhorn Slough. Conduct trapping or seining to characterize fish habitat use, or cores or traps for invertebrates, at the restoration site over time, at control (unrestored) degraded areas, and at healthier high marsh reference sites. An isotope component to compare food webs and trophic dynamics could be included.

Might native *Spartina foliosa* be a viable alternative or addition to hydrological management strategies to combat tidal erosion?

The Slough has no native (or non-native) *Spartina* marshes. Introducing the native species into intertidal mudflats (degraded former pickleweed marshes and bank edges) might increase sediment deposition and decrease bank loss. Carry out literature review and simple modeling to determine where *Spartina* beds could potentially survive at Slough (maximum and minimum estimates of extent), given what is known about elevation and salinity tolerances of the species from elsewhere. Make predictions about effects on tidal erosion / depositional process at the Slough, under maximum and minimum estimates of distribution, based on sediment trapping studies elsewhere.

How are hydrodynamics of the Hester Marsh restoration site changing over time?

The restoration site included excavation of major creeks that were historically present. Are these sufficient to drain the new marsh? Are new creeks and drainages forming? Are poorly drained areas turning into pans? How do hydrodynamics at this site compare to degraded control marshes vs. high marsh references. Track creek development with remote sensing time series and do hydrodynamic modeling.

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How have Parsons Slough assemblages changed since restoration?

This area was opened to tidal exchange in 1980, with initial monitoring of plant and animal communities. Repeat sampling to assess how assemblages have changed. Constructed islands have shrunk due to bank erosion and channels have deepened, so there are likely to be significant effects of tidal erosion that could be documented here.

SALT MARSH LOSS

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

Some regions of the Slough have had extensive marsh dieback over the past decades, while other have had relatively stable marshes, and still others have even seen gain in marsh cover. Correlative studies linking marsh health to factors such as ground table depth, pore water salinity, sediment types, and sulfide concentrations might shed light on causes of marsh dieback. Manipulative experiments could also test the role of potential factors, by altering sediment size, pH, etc..

What are correlates of temporal patterns of marsh loss?

Perusal of aerial photographs from 1931-present suggests that loss rates have not been constant over time. Better quantify temporal patterns in marsh health or extent (over entire time series, or just for past decades perhaps using additional imagery, such as from satellites) and correlate to oceanographic and meteorological conditions, as well as to changes in land use or wetland management.

Can increased freshwater inputs help enhance marsh resilience?

ESNERR staff have determined that the most resilient salt marshes in the estuary appear to be ones with highest freshwater inputs. A field experiment could further examine this potential relationship, for instance by installing roofs that decrease/increase rainfall that particular marsh plots receive, and then track marsh productivity above and belowground, and carbon sequestration rates.

How much marsh area is sustainable with the sediment budget of the Slough?

Marshes need sediment inputs to continue to rise in elevation and track sea level. The Slough has seen drastic changes to sediment dynamics, with decreases due to diversion of the Salinas River, but increases from watershed erosion. Sediment availability to the marsh is also affected by strong currents that export marsh out of the estuary, and by extensive “accommodation space” - extensive lagoonal areas caused by past diking of marshes that compete with marshes for sediment. A sediment budget for the estuary and better understanding of sediment dynamics would greatly inform marsh restoration planning.

What is distribution of brackish plants in Elkhorn Slough?

Brackish plant communities have declined in abundance at Elkhorn Slough over time. We know little about the remaining patches. GPS brackish plant communities and attempt to correlate their abundance with physical factors using GIS analysis.

HISTORICAL BASELINES

What range of environmental conditions were typical at the Slough for the past 5000 years?

Use modern isotope techniques to examine fish otoliths and mollusc shells from Native American shell middens to determine relative marine vs. terrestrial inputs to Slough systems.

Which Slough wetlands today most resemble conditions before major human alterations?

Compare indicator assemblages (e.g. forams) at sites with varying amounts of tidal and freshwater influence today, and take cores at these same sites to assess past assemblages. Is today's main channel foram assemblage most similar to that of the main channel 1000 years ago, or most similar to that of a brackish system like Moro Cojo?

How have eelgrass invertebrate assemblages changed since the 1920s?

Repeat MacGinitie's sampling of eelgrass fauna and look for broad changes (missing species? new invaders?).

What were highlights of aquaculture at Elkhorn Slough over time?

Oysters were cultured in the estuary from the 1920s to 1980s, and sea hares were cultured for a few decades also. There are still some people around who remember where aquaculture took place, what methods were used, and what sorts of issues arose. An oral history project and written summary would be valuable, capturing this information before it is lost.

REGIONAL PATTERNS

How do Elkhorn Slough area brackish marshes compare to others in region?

Most of the Slough's brackish marshes occur in areas with artificial tidal restriction. How do the plant and animal communities of these marshes, and their physical properties such as soils, salinity, and hydroperiod compare to more natural brackish marshes in central California?

How do shorebird numbers at Elkhorn compare to those at other wetlands in the region?

Convert shorebird abundance data at Elkhorn into Slough-wide total estimates, and then compare these to numbers from monitoring programs at Morro Bay, San Francisco Bay, Bolinas Lagoon, etc. Is Elkhorn Slough particularly important for certain bird species?

How do shorebird dynamics at Elkhorn compare to those at other wetlands in the region?

Examine temporal patterns of shorebird abundance from monitoring programs at Elkhorn Slough, Morro Bay, San Francisco Bay, Bolinas Lagoon, etc. Are patterns shared along the coast? For which species?

How do shorebird trends detected by eBird compare to those detected by organized surveys?

Analyze trends of shorebird diversity and abundance for different sites at Elkhorn Slough and San Francisco Bay, from organized long-term monitoring programs vs. eBird data, to determine how they compare and whether eBird may eventually be used to replace formal monitoring.

ECOSYSTEM SERVICES AND HABITAT VALUE

What is the habitat value of vegetated vs. unvegetated estuarine habitats?

Compare larval settlement, fish abundance, etc. in paired areas with and without dense pickleweed (intertidal) or eelgrass (subtidal). Or, using isotopes, compare marsh plant vs. algal sources of N and C in key indicator species (such as commercially harvested fish).

How do ecosystem services of different marsh plant species compare?

In collaboration with ESNERR, examine planted patches of five different high marsh species and quantify a variety of their services, from carbon sequestration to denitrification to hosting diverse animal communities.

What sort of mudflats are most valuable to migratory shorebirds?

Compare eroded, high energy mudflats of lower estuary to depositional (but more eutrophic) mudflats of upper estuary. Compare historical mudflats to mudflats that were recently created due to salt marsh loss (from diking, or from dieback in upper estuary). How does abundance of shorebirds differ in these mudflats? How does their feeding rate?

What is the value of a lagoonal, managed wetland to waterbirds, and does their use vary with oxygen conditions?

North Marsh is a lagoonal wetland that resulted when a former salt marsh was diked and managed for restricted tidal exchange. Oxygen levels plummet in the shallow lagoon each night, but varying levels of tidal exchange have changed average oxygen levels in different periods. The Reserve has 20 years of bird surveys for this wetland (and there is some more intensive recent intern data). Bird abundance and diversity in the wetland could be correlated to oxygen conditions.

What role do microbial biofilms play in stabilizing sediments?

Biofilms may help stabilize sediments, but have never been examined at Elkhorn Slough. What role are they playing in existing banks and marshes? What factors increase or decrease them? Can biofilm colonization at newly restored sites be hastened? This project could involve descriptive components (examining existing biofilms: composition, and where they are more vs. less well developed). It could also involve experiments attempting to stimulate biofilm growth. This could be important for informing a new restoration project, where sediment will be placed on a mudflat to create a salt marsh. Could some sort of inoculation with water and microbes help stabilize these new sediments so they don't wash away?

What do leopard sharks eat while using Reserve as nursery?

Conduct caging experiment to determine which invertebrate species are most affected by shark foraging on the Reserve, and correlate shark abundance to abundance of these species.

Are raccoons playing an important role linking terrestrial and estuarine habitats?

ESNERR camera trapping has revealed high frequency of raccoon visits to estuarine shorelines. Collaborate with ESNERR staff to conduct further camera trapping to examine raccoon distribution, abundance, and foraging in estuarine habitats and adjacent uplands. Conduct isotope analyses on scat to determine importance of estuarine food sources. Conduct caging experiment to quantify raccoon effects on estuarine crabs. Examine whether raccoon abundance or foraging impacts (e.g. on nesting birds) is higher near estuarine margins due to estuarine subsidies.

What are the greenhouse gas mitigation services offered by different estuarine habitat types?

How do carbon sequestration and gas emission rates differ among different natural habitat types in the estuary (marsh vs. mudflat vs. eelgrass bed, etc.), as well as among natural vs. anthropogenically altered habitats (diked marshes, tidally restricted lagoons, nutrient-enriched wetlands, etc.).

POLLUTION AND WATER QUALITY

What are major sources of nutrient-loading to the estuary?

Collaborate with and expand Reserve monitoring to determine flow and concentrations of nutrients entering estuary. One analysis option is to examine samples collected every two hours for 24 hours with an auto-sampler on a monthly basis; this helps to determine whether nutrients are coming in on flooding tides or coming in from the watershed on ebbing tides, and elucidates processes by which incoming nitrate is converted to outgoing ammonia.

Can unmanned aerial vehicles be used to accurately track algal mat abundance and distribution in the estuary?

Algal mats fueled by nutrients are one major concern, and a target of on-going regulatory consideration (total maximum daily load process). A combination of field monitoring and UAV monitoring could be used to help set desired targets and a process of cost-efficient monitoring whether they are achieved.

What is the role of coastal fog in affecting water quality?

Use ESNERR water quality and weather databases to examine effect of foggy weather on water temperature, salinity, and dissolved oxygen.

How is estuarine water quality affected by oceanographic conditions?

Correlate ESNERR water quality data parameters (such as temperature, salinity, oxygen) to oceanographic indices for Monterey Bay, such as upwelling or ENSO index. How does strength of effect differ at a station near vs. far from the mouth of the estuary?

Does water quality correlate with adjacent land uses?

Use our 30 year database of water quality around the Slough, and pick specific case history sites to carry out GIS analysis of links between changed land practices and adjacent water quality.

Are pesticides accumulating in Slough organisms?

Are pesticide concentrations causing chronic toxicity to organisms low in the food web at Elkhorn Slough, and is this resulting in bioaccumulation in birds and mammals?

What are the main sources of fecal coliform bacteria in the Slough?

Concentrations are highest in areas receiving the most freshwater input, but it is not clear whether sources are residential septic tanks or agricultural.

How has sediment loss off farms adjacent to the Slough changed over past decades?

Work with Monterey Public Works to determine how frequency of road scraping (to remove eroded sediment) has changed.

How do high turbidity levels in the water column affect organisms in the slough?

Although it is generally known that high turbidity decreases light availability which can affect algal and zooplankton growth, we could use a good literature review on turbidity effects on species commonly found in the slough, such as the most common fishes and invertebrates. In turn, doing Elkhorn specific surveys of turbidity and animal and/or algal/plankton communities, could be very informative.

INVASIONS BY NON-NATIVE SPECIES

What are the effects of the introduced Japanese mudsnail *Batillaria* on diatom communities and macroalgal mats?

Assess diatom diversity & abundance and/or *Ulva* mats in areas with differing (naturally varying or experimentally manipulated) *Batillaria* densities. Interesting because enormous densities must be changing food webs in Slough, but effect hasn't been documented.

What factors influence *Batillaria* distribution and abundance?

The mudsnails appear to be densest in high elevation intertidal mudflats, particularly in subsided (formerly diked) areas; they are rare along the Slough's main channel. Is this due lower availability of diatom food sources along the main channel? Or higher predation (by crabs, shorebirds?) along the main channel? Characterize environments with high vs. low *Batillaria* abundance and examine growth and predation rates of caged/uncaged snails.

RARE ESTUARINE ENDEMICS

What is behind the reproductive failure of native oysters?

Collaborate with ESNERR staff to track wild oyster reproduction, sample for larvae in the water column, and conduct laboratory experiments examining triggers for reproduction. Analyze water quality and weather data to identify conditions that differed in the years with good vs. bad oyster reproduction.

What are the microhabitat correlates of the threatened brackish snail *Tryonia imitator* and/or tidewater goby?

Collaborate with ESNERR staff on fieldwork to map small-scale and large-scale distribution of these rare species at Slough; correlate to environmental factors (nutrients, pickleweed cover, predators). For the snail (which is not listed), manipulative mesocosm or laboratory experiments could confirm the role of putative environmental factors.

Why have green phoronids become so rare?

In terms of native estuarine biodiversity, the dramatic declines of the green phoronid (formerly a mudflat dominant near the mouth, now virtually absent) is concerning, especially since there are only about a dozen species in this animal phylum. Carry out multi-estuary study to determine microhabitat requirements and environmental tolerances of green phoronids, assess the distribution of such microhabitats at Elkhorn Slough. Could carry out manipulative experiments at sites where they still are abundant (Bodega) to test role of possible limiting factors at Elkhorn (burial with *Ulva*, etc.).

How does species diversity of salt pannes differ from adjacent habitats?

Salt pannes elsewhere have been shown to host various threatened species (e.g., tiger beetles) adapted to the extreme hypersaline conditions; the fauna of Elkhorn Slough salt pannes (e.g., in the North Marsh area) has never been examined; these habitats may be of high value to these rare communities.

MARINE MAMMALS

What correlates with otter behaviors as seen on otter cam?

Review footage from the camera on otters in Yampah Creek and attempt to address questions about correlates of behaviors. Why do all otters appear to flee at once sometimes? How does weather correlate with behaviors or numbers? Etc.

Can otter cam footage be used by community to generate time budgets of behavior?

Work with ESNERR staff to refine draft protocol for tracking otter time budgets with camera footage, and test with local community groups or school classes.

RECREATIONAL USES

How do kayakers and duck hunters influence marine mammal and bird behavior?

Observations to determine whether recreational visitors influence behavior of resident animals; results could lead to management recommendations.

How do mudflat smells affect visitors?

How do visitors respond to the smells of some of the Slough's stinkier mudflats (e.g. North Marsh)? Does the smell affect their experience? Do perceptions of the estuary differ for visitors who encounter the stinky areas vs. less stinky ones? What physical factors (such as depth, tidal range, etc.) correlate with mudflat stinkiness?

What explains visitor use patterns in the Elkhorn Slough region?

Visitors in natural areas seek particular features and activities. What are the expectations of visitors to the Elkhorn Slough Reserve and are these expectations met? Do visitors to our region lack certain experiences that they desire? The answers to these questions can help shape development of future recreational improvements such as trails, parking lots, roads, and boat landings.

2) FRESHWATER AND RIPARIAN HABITATS

THREATENED AMPHIBIANS AND REPTILES

How do various mosquito control practices compare in terms of efficacy and ecological impacts?

Mosquito and other disease vectors are becoming increasingly of concern, spurring control measures with unknown consequences to the Slough's salt and freshwater ecology. Research into the efficacy of these measures weighed against the ecological impacts could help inform better practices. Compare Bt, mosquitofish and native predators such as three-spine stickleback or dragonfly larvae as control mechanisms in 18 Reserve water tanks (guzzlers) or in regional ponds.

What are patterns of Santa Cruz long-toed salamander movement in the watershed?

These very rare amphibians breed in a handful of ponds around Elkhorn Slough. Learning more about movements of juveniles and adults to and from the ponds would lead to improved management, by protecting upland habitat or creating new wetlands within the transit corridors. Note: this work would have to be conducted by someone with a USFWS and CDFW permit, or in collaboration with them.

What are the patterns of habitat use by southwestern pond turtles in the Elkhorn watershed?

Explore aquatic habitats and adjacent areas on the Reserve to locate nesting/breeding sites, count numbers of adults, and track their movements.

What lizard and salamander species are found on the Reserve and what are their relative abundances?

A combination of visual encounter surveys of lizards on the trails and capturing for identification would allow the Reserve to establish a baseline inventory of what species are present and in what abundances. This would be important for future comparisons to establish how populations are faring. A similar survey for salamander species including the placement of coverboards and checking for presence under natural debris would also have importance for future comparisons.

What is the distribution and abundance of amphibian roadkill along Elkhorn Rd. during the rainy season?

Even low levels of traffic are known to have large impacts on amphibian populations near roads. Nighttime or early morning surveys along Elkhorn Rd. during rain events for the duration of the rainy season would allow for quantification of these impacts to local populations, as well as highlight areas where an underpass or culvert could boost rates of connectivity between reserve populations and those off the reserve.

VEGETATION, HYDROLOGY AND RESTORATION

What are the current conditions of aquatic vegetation in the watershed's freshwater wetlands?

Map distribution and types of freshwater habitats in the watershed currently, including aquatic plants and communities as well as hydrological characterization.

What strategies can improve water quality in Reserve freshwater wetlands?

Bioretention pits or heavy mulch to improve quality of freshwater inputs coming from adjacent agricultural fields? Annual dry down and removal of sediments? Bubbling stations to increase dissolved oxygen?

As areas of marginal or unsustainable farmland in the watershed are restored to native habitat, can we see a change in local groundwater supplies?

Can we quantify the amount of rainwater that is infiltrated to the aquifer from this change in land use? Could this be a way to help balance the groundwater overdraft regionally?

GROUNDWATER DYNAMICS

What are the links between groundwater and surface water?

Have past changes to the Slough's tidal prism (e.g., return of tidal exchange to Parsons complex) affected local groundwater (saltwater intrusion)? How would future changes to the tidal prism of different wetlands (moderate decreases at Parsons, slight increases at South Azevedo, etc.) affect adjacent groundwater? Does surface impoundment of freshwater (e.g. in Moro Cojo area wetlands) help to restore groundwater and decrease saltwater intrusion?

3) COASTAL PRAIRIE

GRAZING AND OTHER RESTORATION TECHNIQUES

What is the impact of cattle grazing on native plants and animals.

The Reserve has three grazed peninsulas, and these are interspersed with three ungrazed peninsulas. Staff have collected before drone imagery for all six grasslands; a researcher could follow up with after imagery to compare vegetation types visible in the aerials (for example native creeping wildrye or non-native mustard). Staff have vegetation transects in all six areas, including both before and after data; but plant assemblages in both treatment types could be better characterized. Animals could be compared between the grazed and ungrazed grasslands.

How does grazing pressure differ in grasslands with more vs. less native species?

Use camera traps to quantify grazing in varying types of grasslands, including ones dominated by native grasses vs. by weedy forb patches.

What is the effect of species diversity on invasibility?

Do grassland restoration with multiple species, singly and in combinations, to look at whether species mixes are more effective than single species at preventing invasion by non-native species.

Do grassland monocultures or mixed plantings succeed better in restoration plantings?

The Hester restoration project on ESNERR offers an opportunity to try grassland restoration experiments in an area where topsoil and the weedy seed bank have been removed. Up to 20 acres of scraped upland will be available for restoration science projects in 2020-2022, and grassland planting projects including different species or planting techniques could be an ideal fit for this area. Plantings completed in 2019 show that native plugs and seeds can do well at the project site.

What is the effect of patch size on restoration success?

Plant natives in degraded grasslands in patches of varying sizes to determine whether bigger areas resist invasion better than do smaller ones.

SPATIAL PATTERNS OF PRAIRIE DISTRIBUTION

Where are remaining stands of intact coastal prairie, and what do they correlate with?

Fieldwork to find remaining native grasses stands, and GIS work to determine whether land use history, current management, slope, surrounding vegetation type, proximity to wetlands, etc. explain distribution of species in the watershed.

How to soils correlate with native cover?

Compare soil properties in areas with high vs. low native grass cover, to determine conditions that appear to favor natives. These might be the most promising sites for restoration work.

RARE PRAIRIE ENDEMICIS

What is the foraging efficiency of the many sensitive raptor populations in various types of grasslands in the watershed?

Anecdotal information suggests that thatch accumulation increases vole abundance, and yet raptors forage more frequently in grazed areas with little thatch accumulation. Are these observations born out by more scientific methods? What characteristics do grasslands exhibit that support raptor foraging?

What is the distribution and habitat use of the listed Salinas Harvest Mouse and Salt Marsh Ornate Shrew?

These species are endemic to a small area around Elkhorn Slough, and haven't been studied since the 1950s; their taxonomy and ecology should be revisited so that their small populations can be wisely managed.

Does seed number limit introduction of Santa Cruz tarplant and other species?

This species is endemic to coastal prairie and one of the few remaining populations is in the Elkhorn Slough watershed at the Porter Ranch. Research to date has suggested that the number of seeds in any particular population's soil seedbank may be key to long term survival of the species. This may be because of the species' ability to withstand year-to-year stochasticity or it may have more to do with low-level chemical compounds deterring herbivory. Experiments with this and related species may help determine the influence of seed number to the survivorship of experimental coastal prairie wildflower introductions.

HABITAT USE OF PRAIRIES

How important are prairie, salt marsh and freshwater wetlands for foraging by raptors at Elkhorn Slough?

Various raptors such as Red-tailed hawks and White-tailed kites nest on the Elkhorn Slough Reserve, but little is known about where they spend their time foraging, and what they feed their young. The mosaic of adjacent habitat types allows observation of relative importance for foraging and prey sources, and how this changes with seasons or between years (wet vs. dry, etc.). Cameras could be placed at raptor nests (such as the one of a reliable Red-tailed hawk pair that breeds on the Reserve) to observe prey items delivered to young. Observations of foraging linked to spatial data on habitats could address broad questions of foraging. Isotope analyses could reveal importance of marsh vs. terrestrial food webs.

How does habitat use differ on lands of different ownership?

Do field surveys or camera trapping to compare abundance of birds or mammals in lands under conservation ownership, farm ownership, residential ownership in the watershed (must obtain permission of private landowners).

How does poison hemlock influence community composition?

Examine diversity and abundance of some native plants or animals (e.g., songbirds; grasshoppers in areas with hemlock and areas where hemlock has been removed).

What effect does herbivory have on prairie plants?

Conduct caging experiments to exclude herbivores of different sizes (snails, rodents, deer, etc.) and compare plant community vs. control sites.

How are large predators using Elkhorn grasslands and surrounding landscape?

Which large predators are present? Are their populations viable? What movement pathways are they using, and how large is their range? Do protected lands such as those managed by ESNERR and ESF provide important refuges or connectivity?

4) MARITIME CHAPARRAL

How can manzanita best be propagated?

Various species of manzanita (*Arctostaphylos* spp.) comprise a key component of maritime chaparral habitat. Some species are highly endemic and even the more widespread ones may have important local genetic adaptation. We thus would like to use locally collected material in restoration projects, but are unsure about the best methods for doing so, especially since manzanita has evolved with fire and appears to grow best after fires. Students could compare different methods such as Fall/Winter cuttings collection and propagation; fall berry collecting and stratification; liquid smoke; fire germination and biochar trials.

What is the effect of drought on manzanita?

Track manzanita health with field surveys and remote sensing through wet and dry years.

Explore the value of conservation easements and model effectiveness of conservation banking strategies.

Map current conservation easements, document their past and present condition, and evaluate their ecological value. Help design baseline characterization and monitoring programs for chaparral easements. Or, evaluate the benefits of a maritime chaparral conservation banking program in the watershed.

5) COAST LIVE OAK

HABITAT VALUE RELATIVE TO EUCALYPTUS

How do ecosystem processes differ in oak woodlands vs. eucalyptus groves?

For instance, how does water usage differ between the two tree species? How does nutrient cycling differ?

What is the value of oak vs. eucalyptus groves for native bird species?

Preliminary work has shown similar bird species composition in oak vs. eucalyptus groves. It would be interesting to track fitness parameters (nesting success, survival, etc.) to see whether the two woodland types are different or equivalent for particular bird species.

OAK RESTORATION

How can native oak understory be enhanced?

Experiments with various methods to initially remove and then to discourage re-establishment of non-natives. Include comparison of areas with varying canopy cover and proximity to edge to determine where long-term success is most likely.

What is the best method to remove periwinkle?

Periwinkle (*Vinca major*), is a non-native invasive oak understory herb species that is very widespread. What is the best way of removing it without harming the oaks? Methods may include black tarping, herbicide, scraping, and others. How might the removal methods affect the soil surrounding oak trees (under the oak canopy) and might this have an effect on the health of the oaks?

WOODLAND CAVITY NESTERS

What are the effects of providing nestboxes to cavity nesters?

We have 150 nestboxes used mostly by chestnut-backed chickadees (CBCH). Does providing nestboxes increase CBCH densities? (can compare woodlots with and without nestboxes). Does providing nestboxes increase CBCH reproductive success (have to find natural nests in cavities to make this comparison). Does neotropical migrant density correlate with CBCH density (it has been suggested that neotropical migrants are attracted to CBCH and preferentially flock with them)?

6) CROSS-HABITAT

How has land cover/land use changed in the Elkhorn watershed over the past decades?

A detailed GIS mapping effort was conducted about 15 years ago. This could be repeated now, to quantify trends and changes, in particular those resulting from land acquisition and restoration.

What is the best approach for managing, processing, and interpreting UAV data?

An enormous amount of data (e.g. RGB imagery, multispectral imagery, digital elevation models (DEMs) are collected with each UAV overflight, and we need improved approaches for archiving and processing them. Currently, DroneDeploy offers automated mosaicing services for both RGB imagery and DEMs, but they are not capable of refining the data to the level of accuracy that we require. Additionally, interpreting the data into meaningful results and summaries of habitat change requires a great deal of time, even with the help of semi-automated classification software packages. In other words, we collect more data than we can handle. Investigating novel ways of streamlining the UAV data backlog will be required in the future.

How can traditional ecological knowledge help us understand past habitat management and provide insights into future strategies?

Very little is known about how humans interacted with Elkhorn Slough landscapes for the past 10,000 years. Learn more for tribal communities interacting with similar habitats and use that to understand changes that have occurred in the past centuries and potentially how to reverse them.

How can prescribed burns help manage Elkhorn Slough landscapes?

Compile literature on the potential risks and rewards of burning, and on past burning frequency in this region. Conduct field surveys for geophytes, which can serve as indicators of past burning.

What factors influence recovery of agriculture lands?

The Elkhorn Slough Reserve and Foundation have taken some agricultural lands out of production in the past decades. A variety of passive and active restoration approaches have been implemented to enhance recovery by native vegetation. Compare recovery trajectories of

different areas and correlate changes to site conditions and to management approaches, using remote sensing and field-collected indicators such as soil carbon or native plant diversity.

What are patterns of bird mortality resulting from the Highway 1 bridge?

Anecdotal observations have found that there are episodically many roadkill birds in the Highway 1 bridge over Elkhorn Slough, but patterns have never been documented. Camera traps and counts of birds in the area and of carcasses could quantify bird usage and mortality in the area, and how it varies by species, time of day, season, etc. A better understanding might lead to recommendations for measures to decrease mortality, for instance by placing high poles/flags along the railings to discourage roosting.

How do below-ground processes affect restoration success?

Transplant plants in restoration areas (grassland, chaparral, marsh, oak, etc.) with and without pieces of soil crust or soil cores taken from intact habitats to compare survival and growth.

How are surface water and groundwater linked in the Elkhorn Slough Watershed? Are certain areas more suitable for managed aquifer recharge? Has the cessation of groundwater pumping from old agricultural lands owned by the Reserve and Foundation resulted in measurable changes to groundwater or surface water quantity or quality? Has the restoration of agricultural lands resulted in increased groundwater infiltration?