

Elkhorn Slough, California: **STATE OF THE ESTUARY REPORT**

A report on temporal trends in estuarine indicators monitored by
the Elkhorn Slough National Estuarine Research Reserve



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How are different indicators of estuarine ecosystem health changing over time?

The focus of this report is on changes over time, using long-term monitoring data to detect trends in indicators that would suggest that aspects of ecosystem health or function at Elkhorn Slough are improving, degrading, or remaining stable. These monitoring data have been used to detect crises and stimulate management intervention, to identify local vs. regional patterns, to serve as baselines for restoration projects, and to correlate trends to weather patterns or human actions.

This report provides highlights of temporal trends in key indicators monitored by the Elkhorn Slough National Estuarine Research Reserve, owned and operated by the California Department of Fish and Wildlife in partnership with the National Oceanic and Atmospheric Administration and the non-profit Elkhorn Slough Foundation.



Monitoring programs are coordinated by Elkhorn Slough Reserve staff members, but many of the data are collected by Elkhorn Slough Reserve volunteers acting as highly trained citizen scientists.

The information here consists only of selected examples; much more information on the monitoring programs, data, and results can be found at the web links provided on each page.

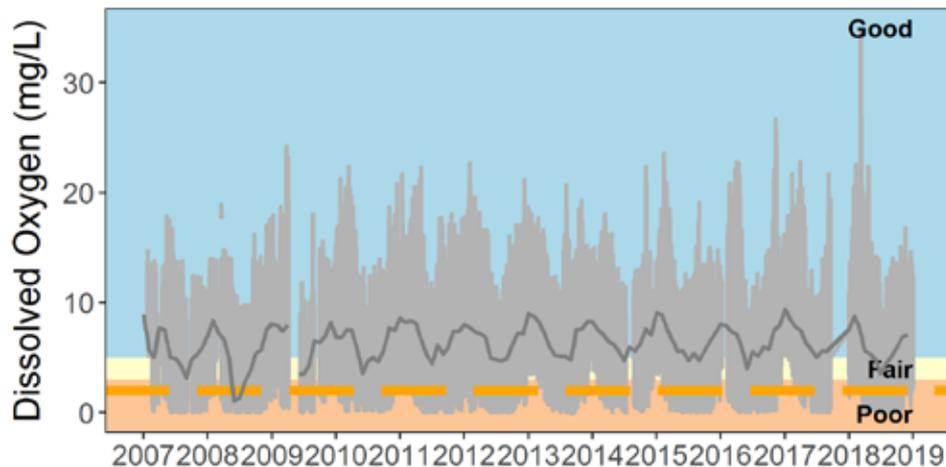
OXYGEN HAS REMAINED STEADY OVER TIME, BUT VARIABLE ACROSS SITES

Hypoxia (dangerously low oxygen concentrations, in the red zone on the graph below 3 mg/L) is rare at sites with strong tidal exchange, such as South Marsh, but common at sites with artificially restricted tidal exchange, such as North Marsh. No clear long term trends emerge. Note scale of North Marsh oxygen concentrations are much higher than South Marsh fully tidal site. Also note oxygen concentrations range in the poor zone much more often in the tidally restricted site (North Marsh) than the fully tidal site South Marsh.

[See http://www.elkhornslough.org/research/waterquality_nerrs.htm for more information]

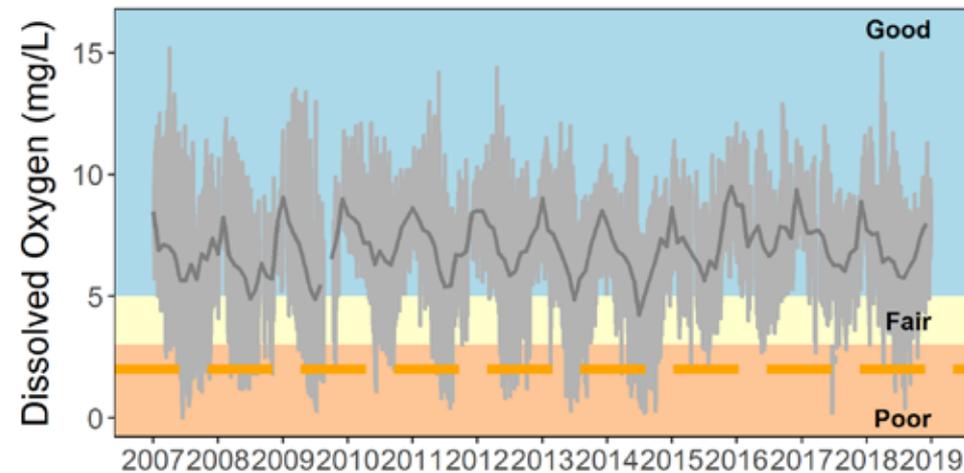
North Marsh (NM)

— Data (2007-2018) — Monthly Average (2007-2018)



South Marsh (SM)

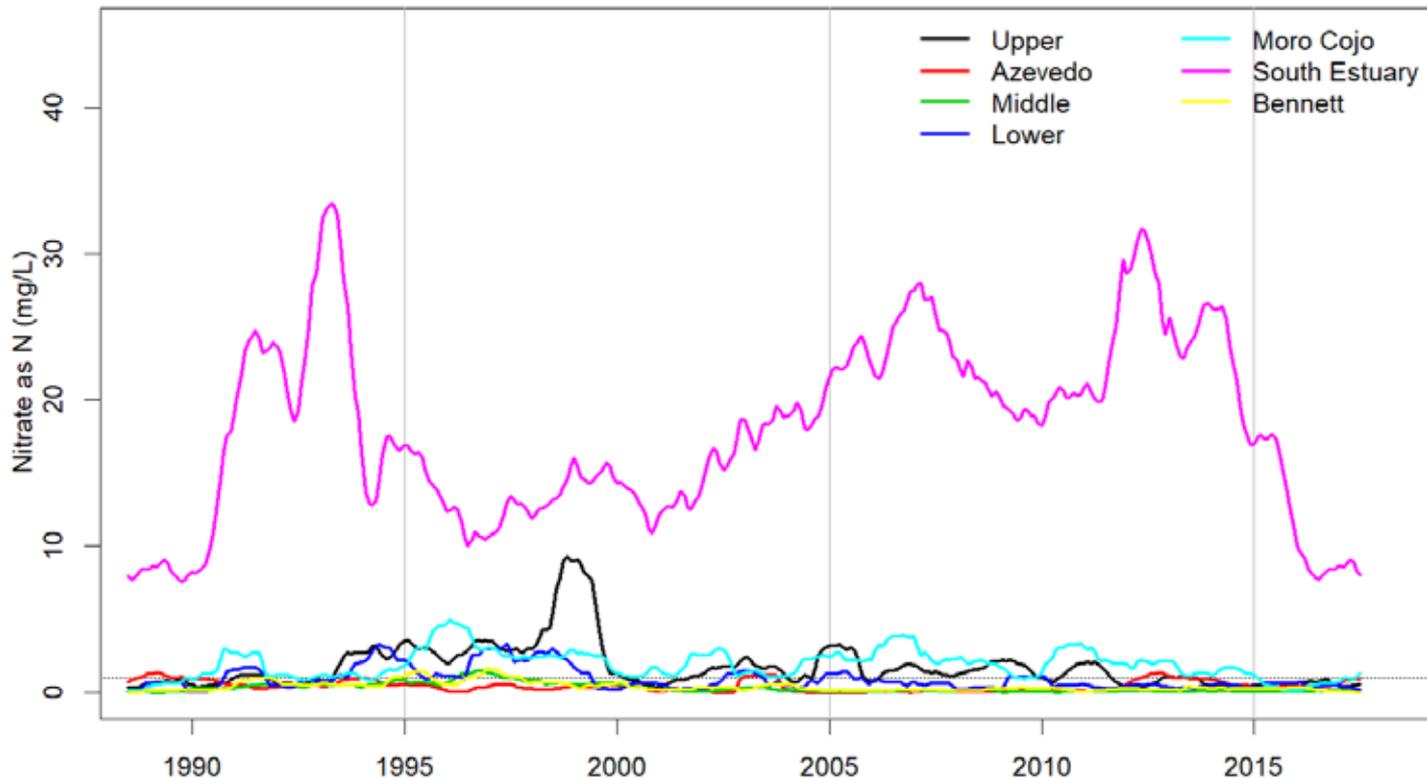
— Data (2007-2018) — Monthly Average (2007-2018)



NUTRIENT POLLUTION VARIES BY REGION AND OVER TIME

Seasonally weighted averages of nitrates appear to undergo cycles of low vs. high years; currently we are in a lower phase. Nitrates are highest and steady in the Southern Estuary sites and still well above the unhealthy threshold of 1 mg/L. All other regions are below this threshold other than Moro Cojo that is just above.

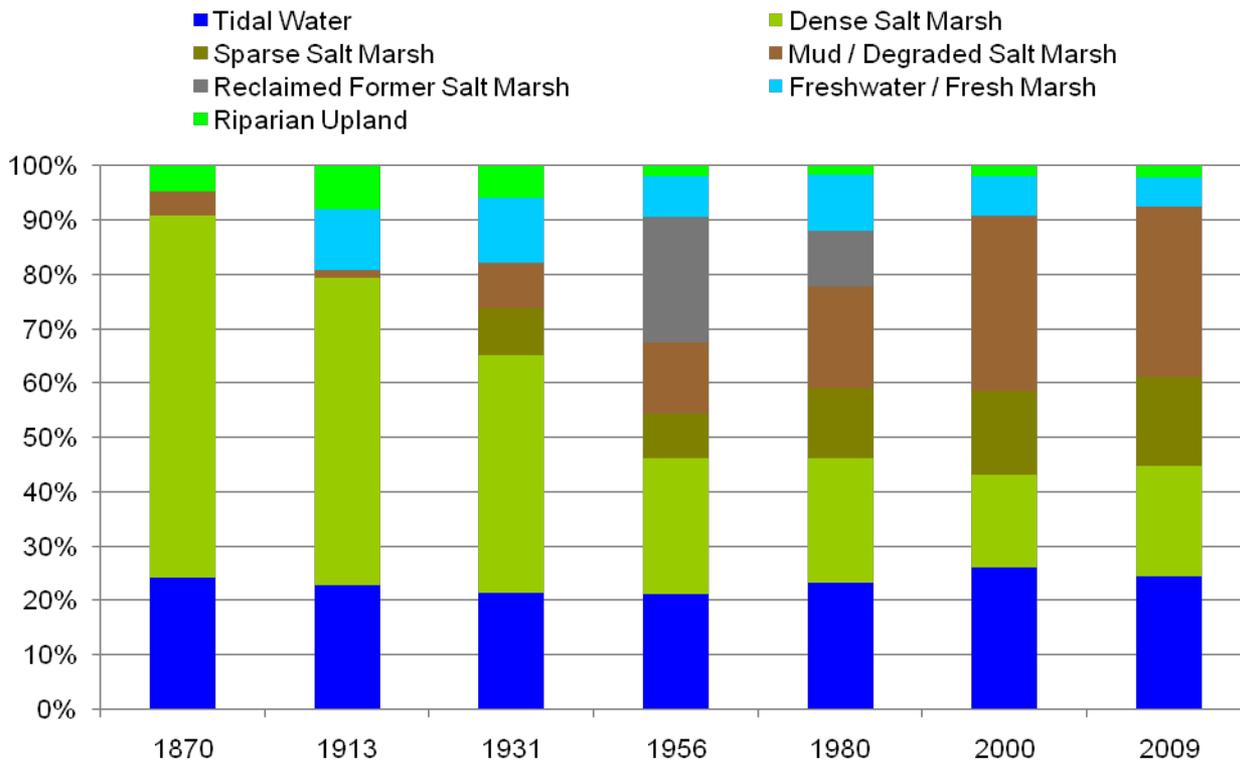
[see http://www.elkhornslough.org/research/waterquality_volunteer.htm]



OVER THE PAST 150 YEARS, ESTUARINE HABITAT DISTRIBUTION HAS CHANGED

Analysis of maps and aerial photos reveals a significant decrease in dense salt marsh and increase in mudflat and sparse salt marsh over past 150 years, but greater stability in the past decade. Marsh loss has multiple causes, including human changes to tidal exchange and sediment supply.

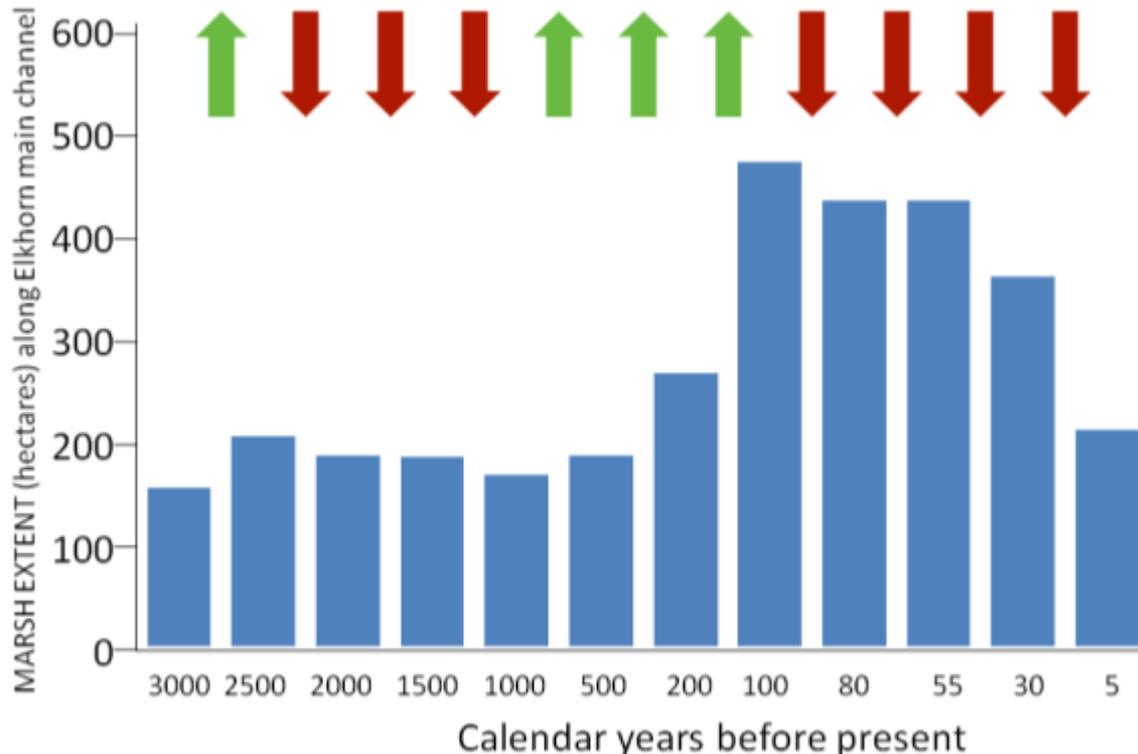
[See http://www.elkhornslough.org/research/conserv_marsh.htm for more information]



OVER THE PAST 3000 YEARS, SALT MARSH EXTENT HAS VARIED GREATLY

Analysis of paleo-ecological cores reveals that marsh extent has been variable over time. There was a significant increase in marsh extent a few hundred years ago, but this has been followed by a sharp decline.

[See http://www.elkhornslough.org/research/conserv_marsh.htm for more information]

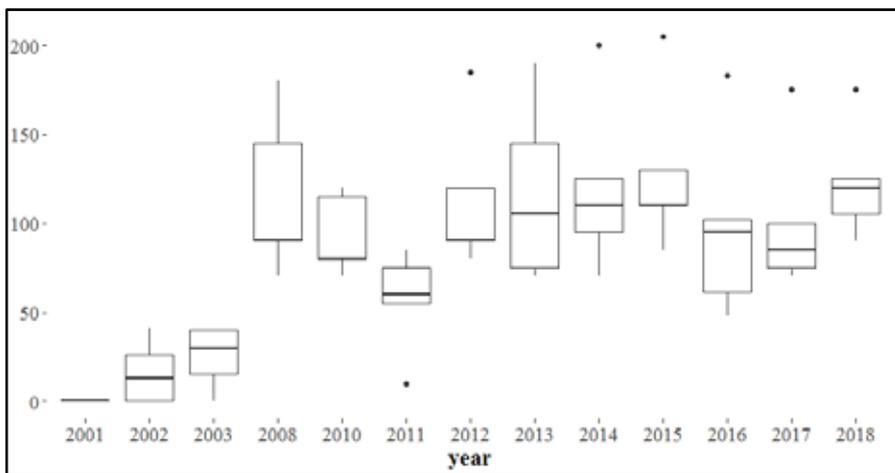


SALT MARSH-UPLAND BOUNDARY HAS MIGRATED LANDWARD



The location of the boundary between the salt marsh and adjacent uplands is higher (landward) now than in earlier monitoring years. The upward migration is due to increased inundation of this zone with seawater. The peak was during regional high water levels in 2014-2015.

Top of ecotone
(cm from marker)



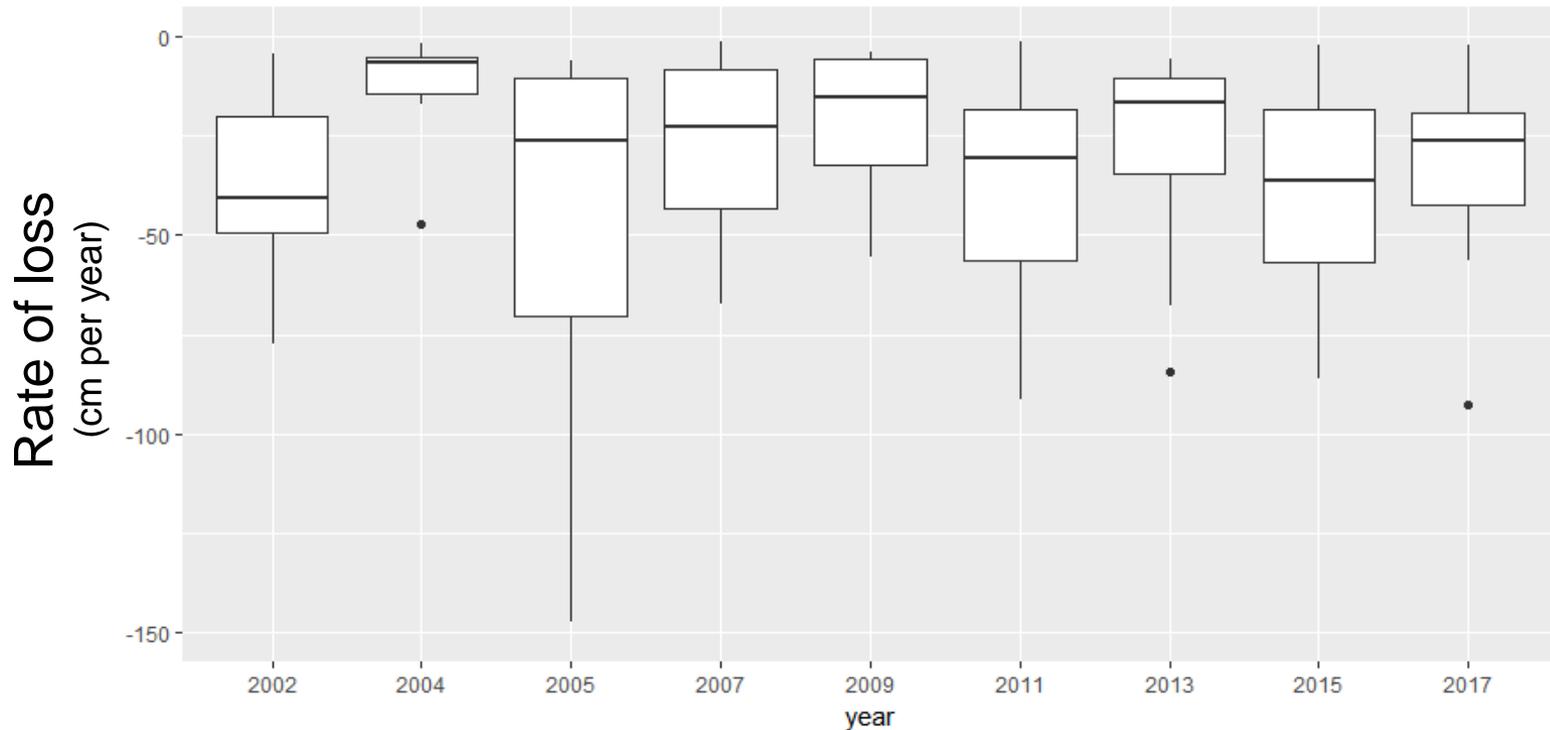
[See

http://www.elkhornslough.org/research/co_nserv_ecotone.htm for more information]

CHANNEL BANKS CONTINUE TO ERODE

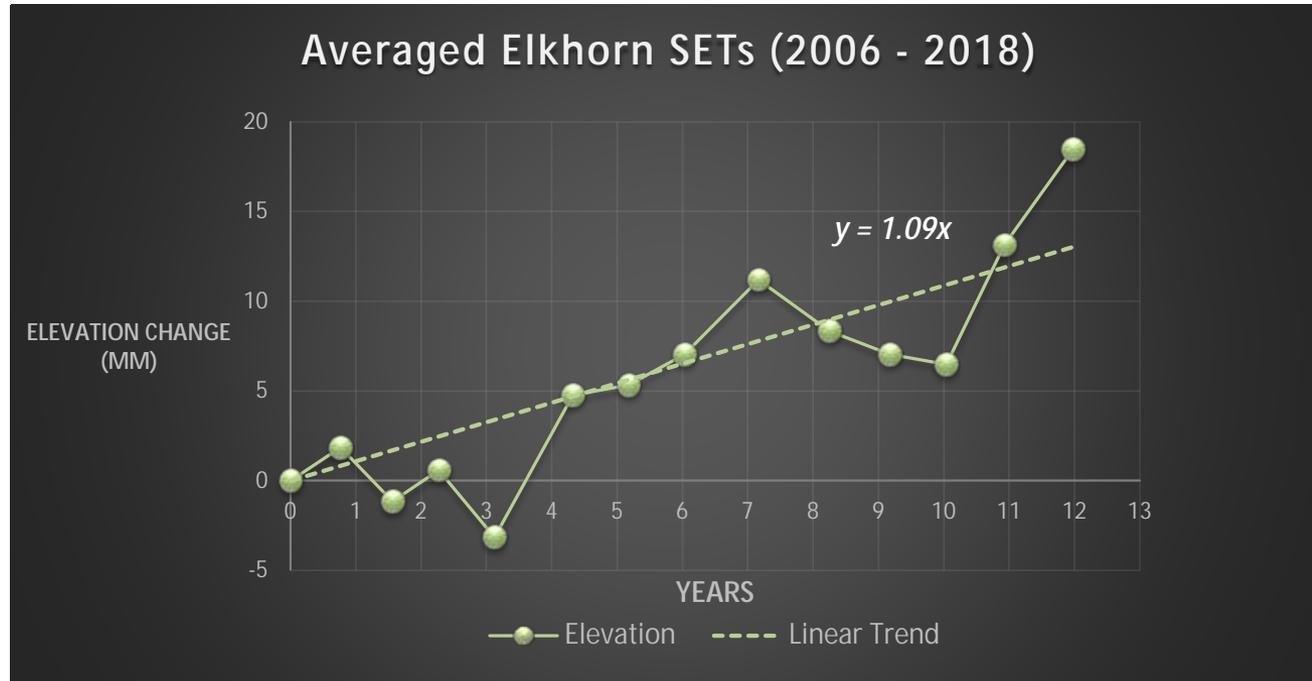
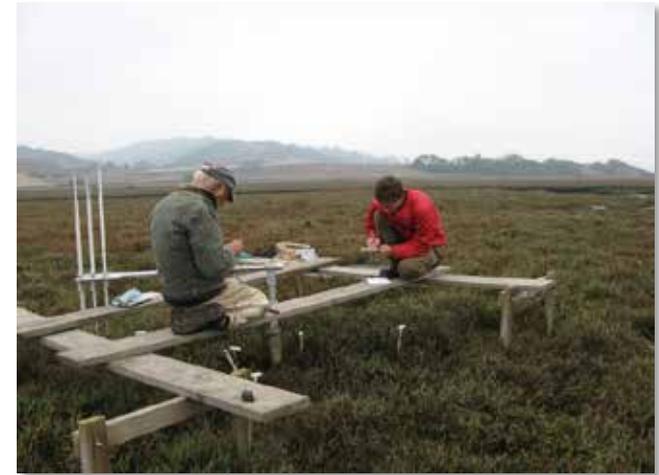


Along the channels of Elkhorn Slough, bank edges continue to erode, at variable rates over time and space, but averaging around 30 cm/year. [See http://www.elkhornslough.org/research/conserv_erosion.htm for more information]



MARSH ELEVATION GAIN (1.09 mm/yr) vs. SEA LEVEL RISE (1.48 mm/yr)

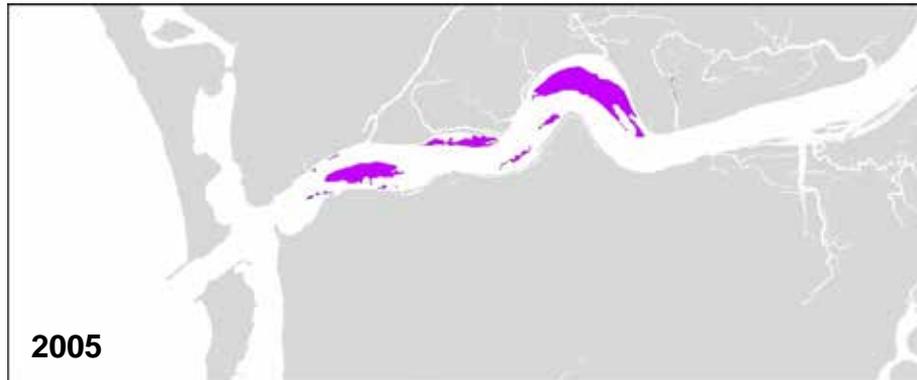
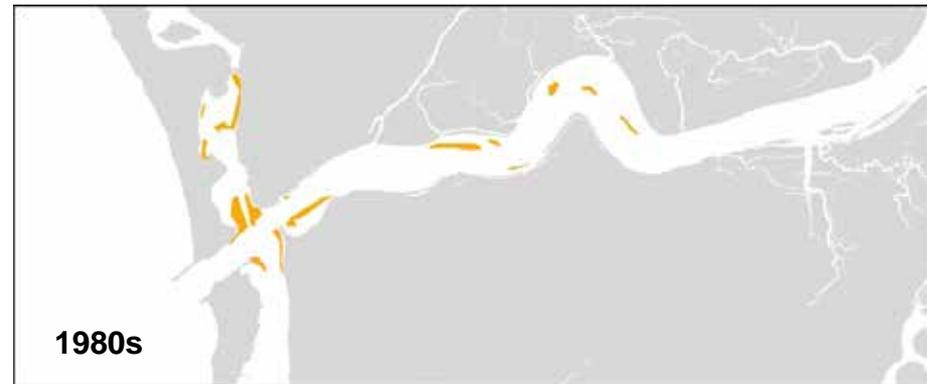
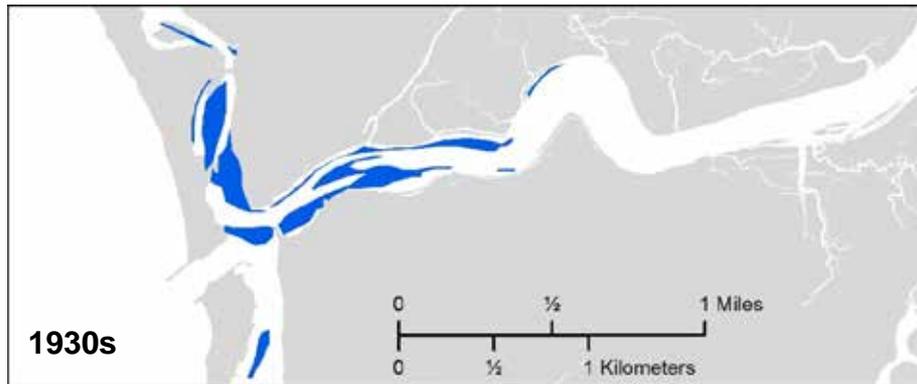
Surface Elevation Tables (SETs) measure precise changes in the elevation of the marsh surface. Averaged together, results show the marsh is not keeping pace with sea level rise, likely due to subsidence.



EELGRASS HAS RECOVERED IN PAST DECADES

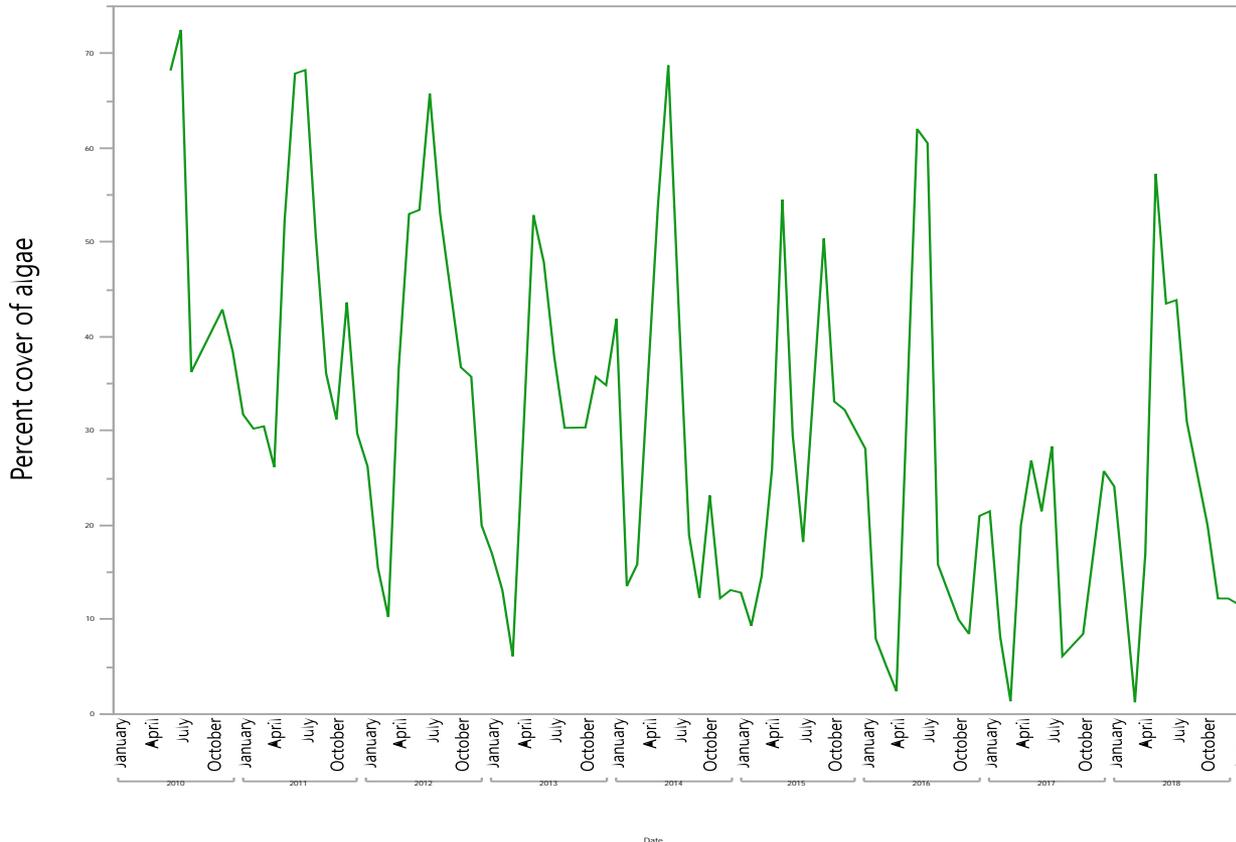
Analysis of aerial photos reveals dramatic loss of eelgrass beds in harbor area and lower Elkhorn Slough, followed by a period of recovery in the 1990s to the present.

[See <http://www.elkhornslough.org/research/gis.htm> for more information]



ALGAL MATS PEAK IN SUMMER

Algal production is fueled by nutrients. Monthly monitoring at eight sites around the estuary reveals strong seasonal trends, with peaks in summer. 2016 had the highest algal cover since monitoring began.



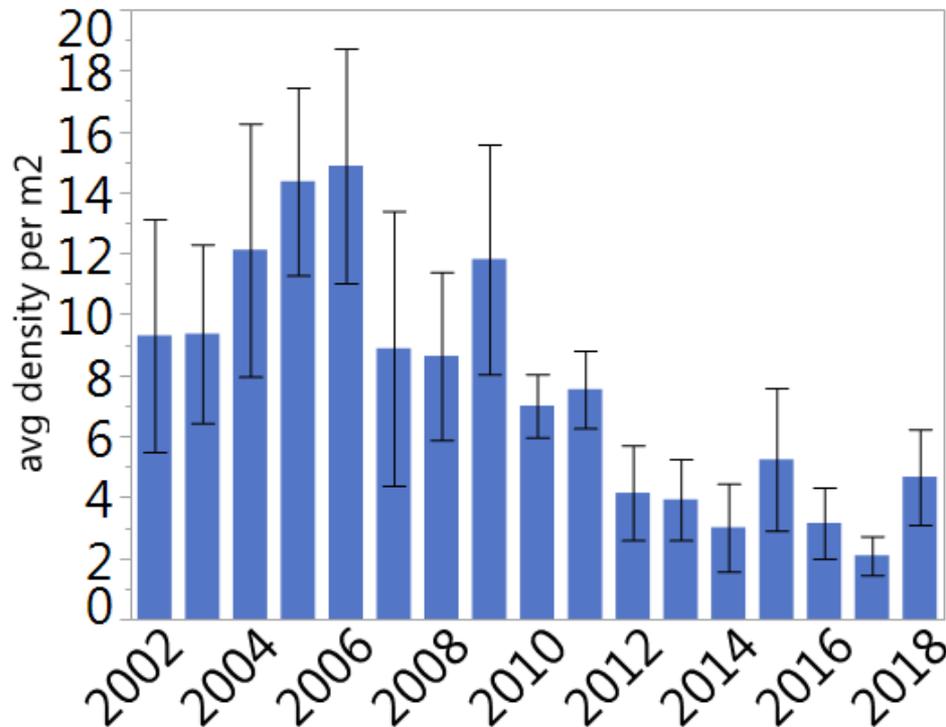
Algae at Hummingbird Island, June 2014



Algae at Vierra Beach, June 2014

LARGE MUDFLAT CLAMS AND WORMS ARE LESS ABUNDANT IN THE LOWER ESTUARY

Field surveys at permanent transects have shown that number of large burrowing invertebrates (fat innkeepers, gaper clams, and butter clams) has decreased over the past years. Nevertheless, clams and large worms remain quite abundant in the lower estuary. [See http://www.elkhornslough.org/research/biomonitor_invert.htm for more information]



Fat innkeeper

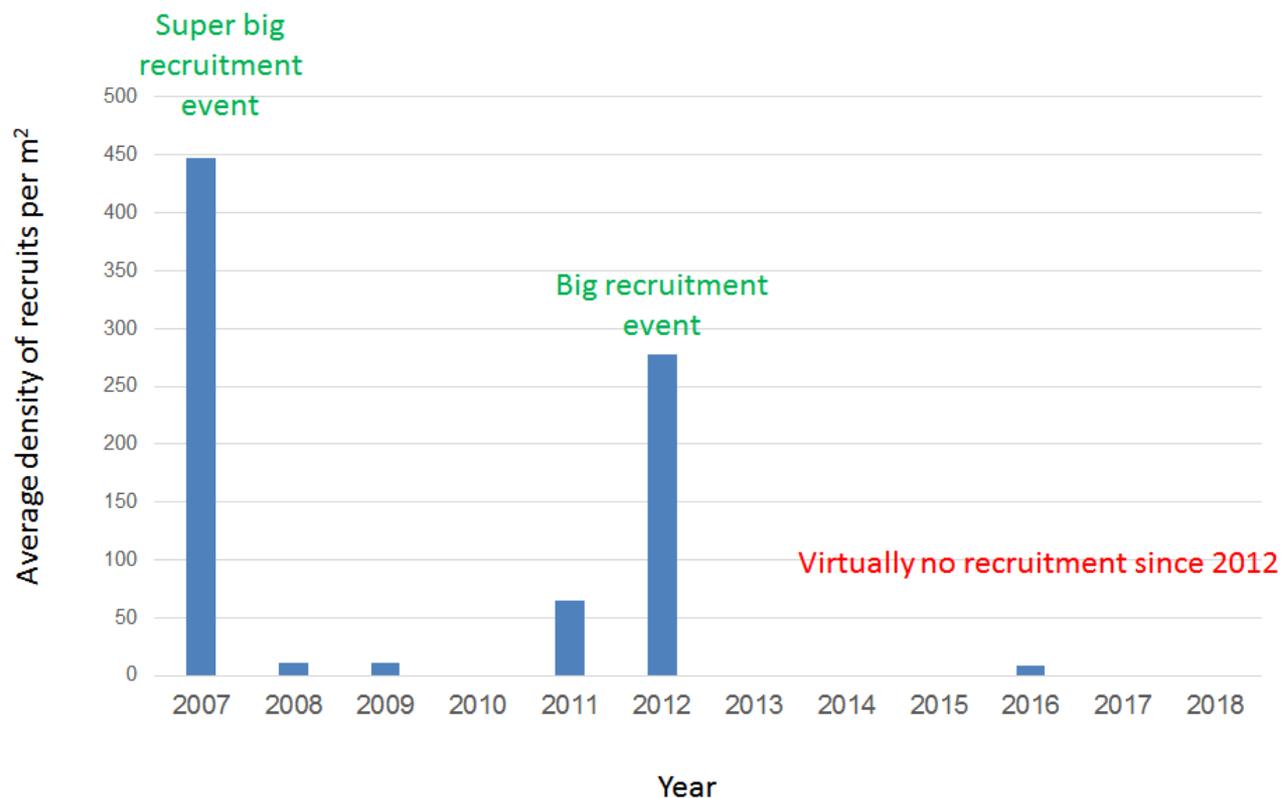


Gaper clam

NATIVE OYSTER SHOW RECRUITMENT FAILURE IN MOST YEARS

In most monitoring years, there was zero recruitment of juveniles (on tiles being monitored). This low recruitment poses risk for sustainability of oysters in the estuary, and is being addressed by raising juveniles in the lab to outplant.

[See http://www.elkhornslough.org/research/conserv_oysters.htm for more information]



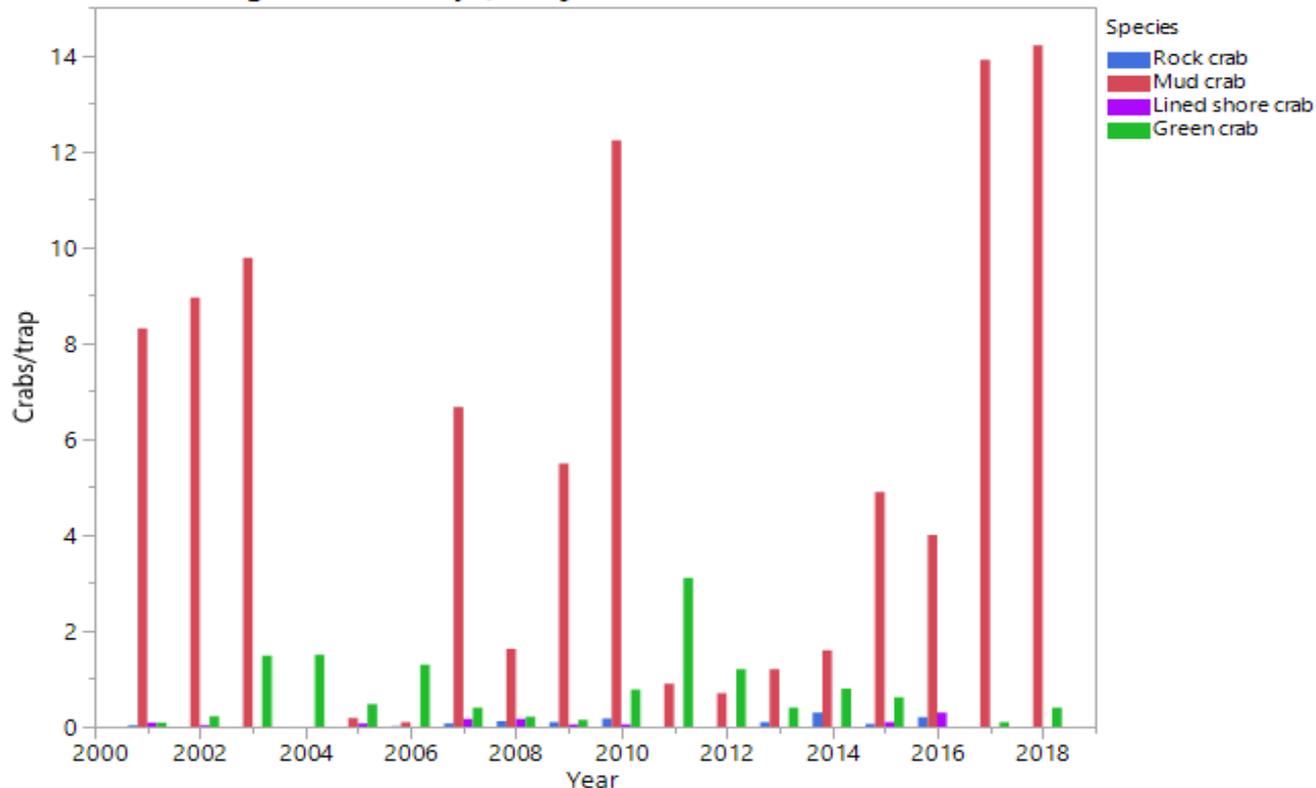
CRAB NUMBERS ARE HIGHLY VARIABLE

We monitor crabs annually at two sites.

Generally, abundance of native mud crabs is high while abundance of non-native green crabs is lower. Green crabs were at their lowest in 2016.

[See http://www.elkhornslough.org/research/biomonitor_invert.htm for more information]

Large minnow traps, Kirby Park and South Marsh



Rock crab



Mud crab



Lined shore crab

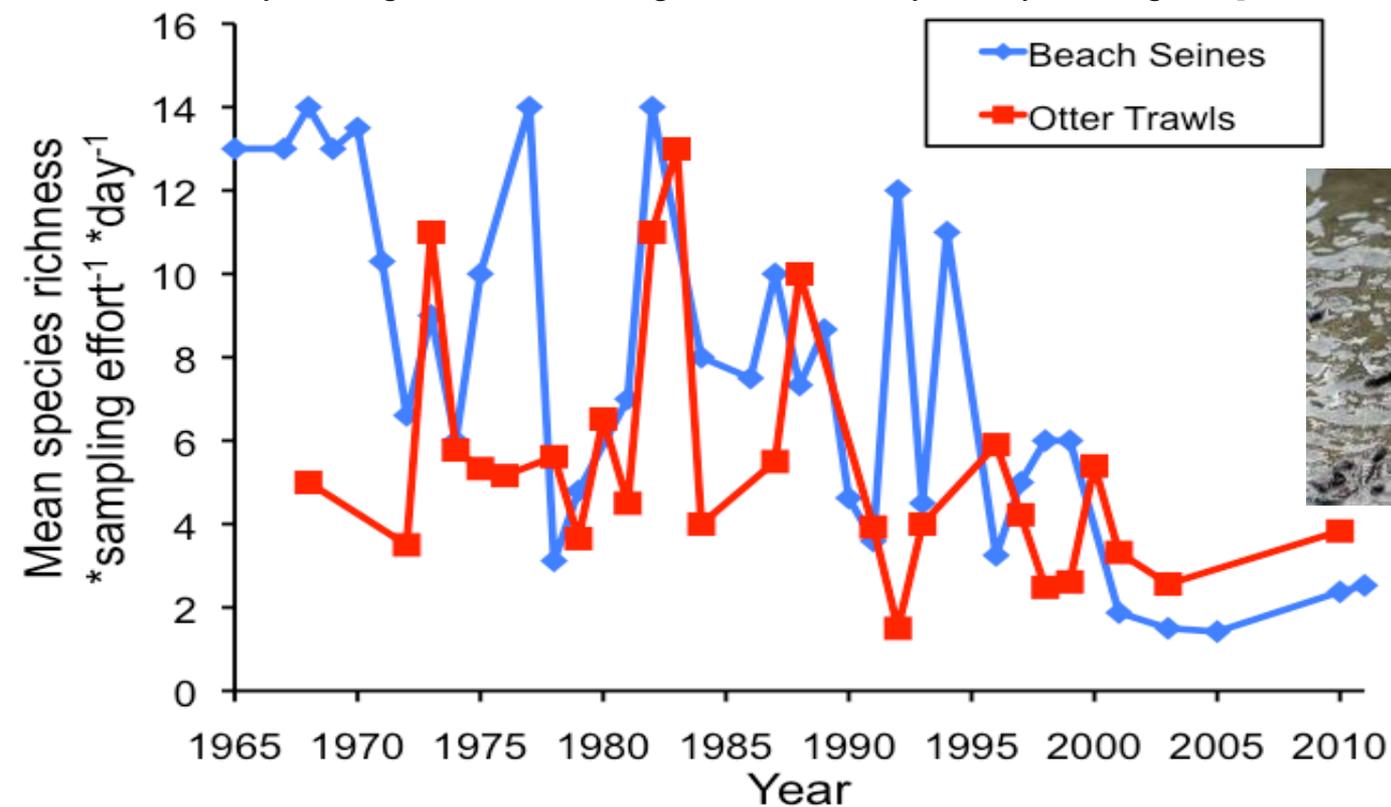


European green crab

FISH DIVERSITY HAS DECLINED IN ELKHORN SLOUGH OVER THE PAST DECADES

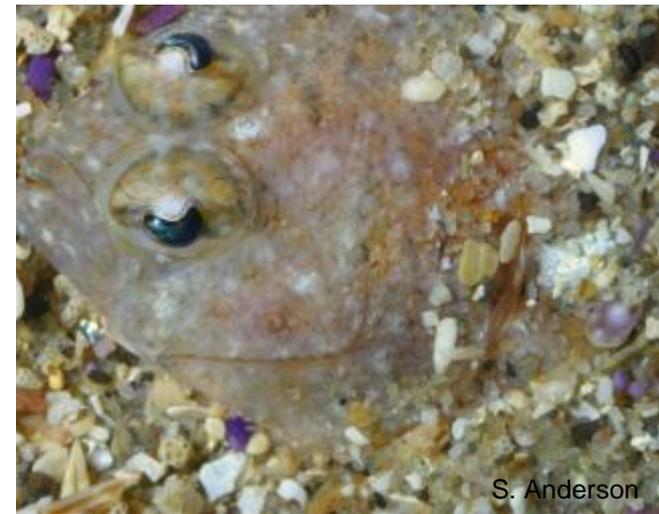
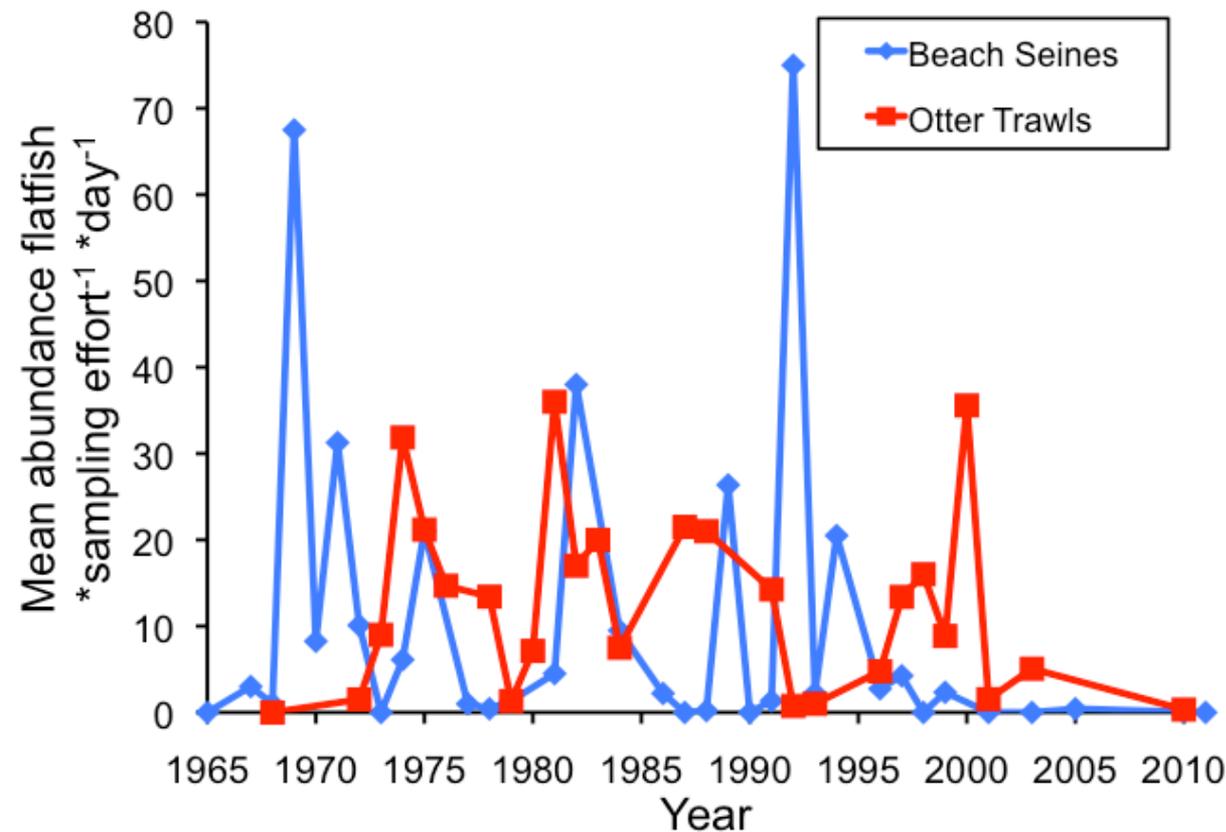
Both beach seines and otter trawls reveal a decrease in average fish species richness (number of species) in the Elkhorn Slough main channel over time. Peak diversity observed in 1970s-1980s has not been observed in past two decades.

[Data from multiple sources made available by the Monterey Bay National Marine Sanctuary's Integrated Monitoring Network, analyzed by B. Hughes.]



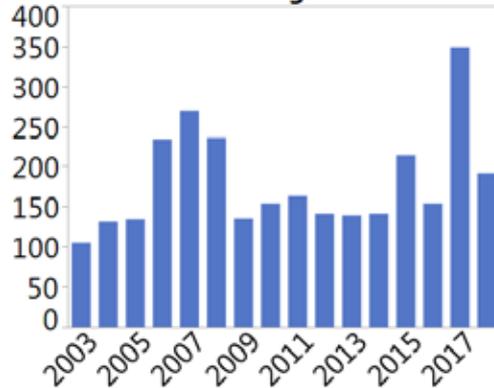
FLATFISH ABUNDANCE HAS DECLINED IN ELKHORN SLOUGH OVER THE PAST DECADES

Both beach seines and otter trawls reveal a decrease in average abundance of flatfish in the Elkhorn Slough main channel over time. Numbers have been especially low in the **past decade**. [Data from multiple sources made available by the Monterey Bay National Marine Sanctuary's Integrated Monitoring Network, analyzed by B. Hughes.]

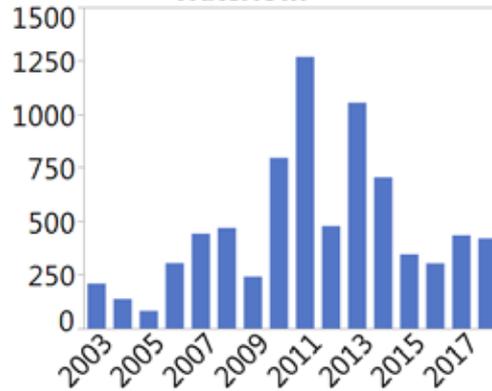


WATER BIRDS ARE ABUNDANT IN THE ESTUARY

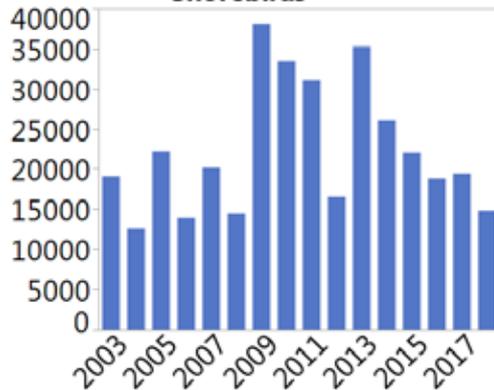
Hérons and egrets



Waterfowl



Shorebirds



Thousands of shorebirds and hundreds of waterfowl and waders are detected in annual bird surveys. There is considerable interannual variation in abundance, not synchronized between bird groups, and no clear trends. [See

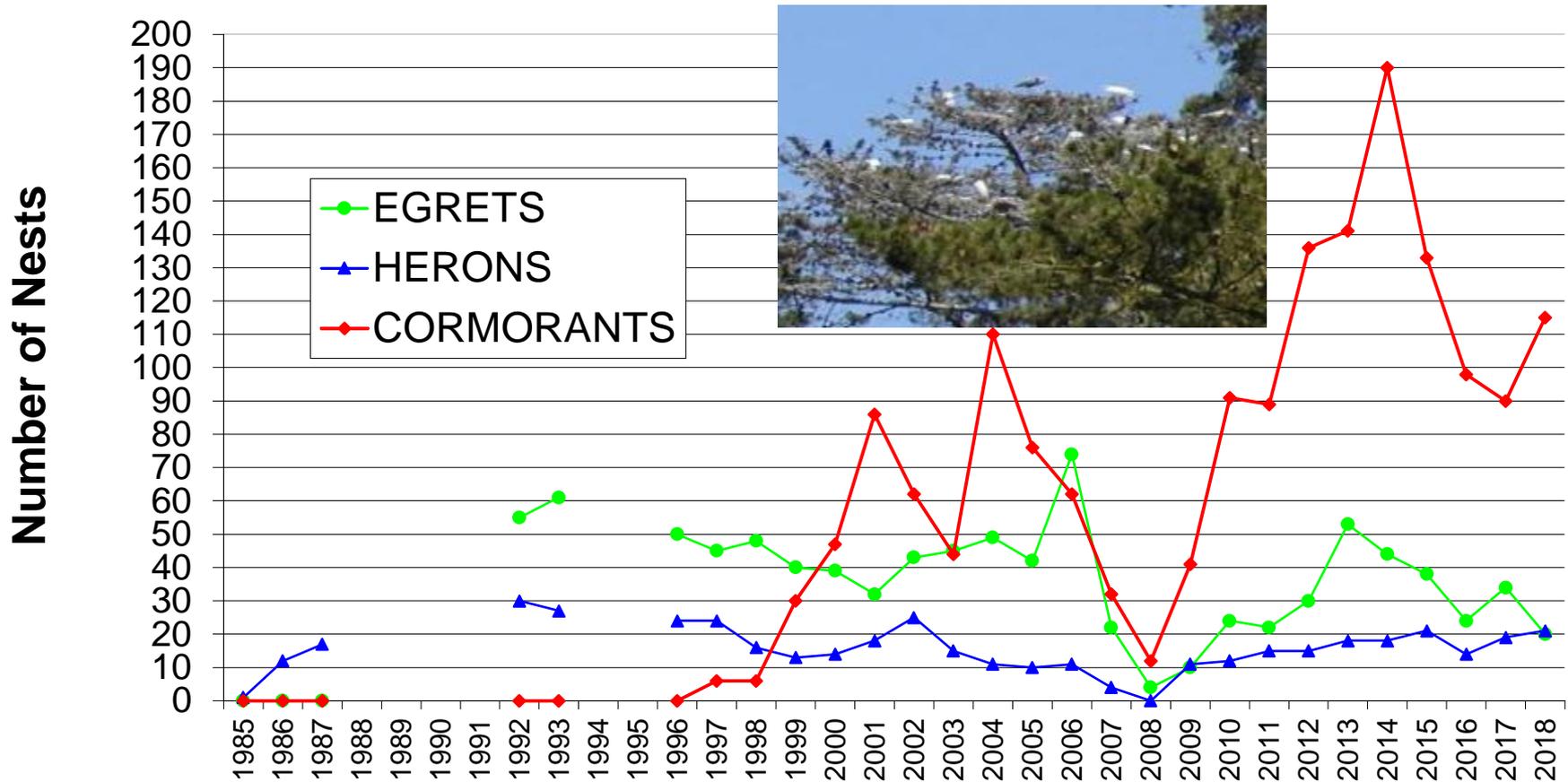
http://www.elkhornslough.org/research/bird_esnerr.htm for more information]



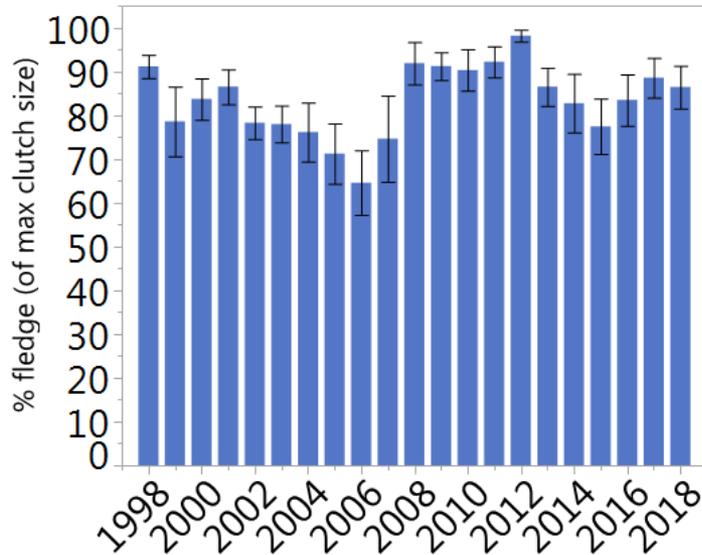
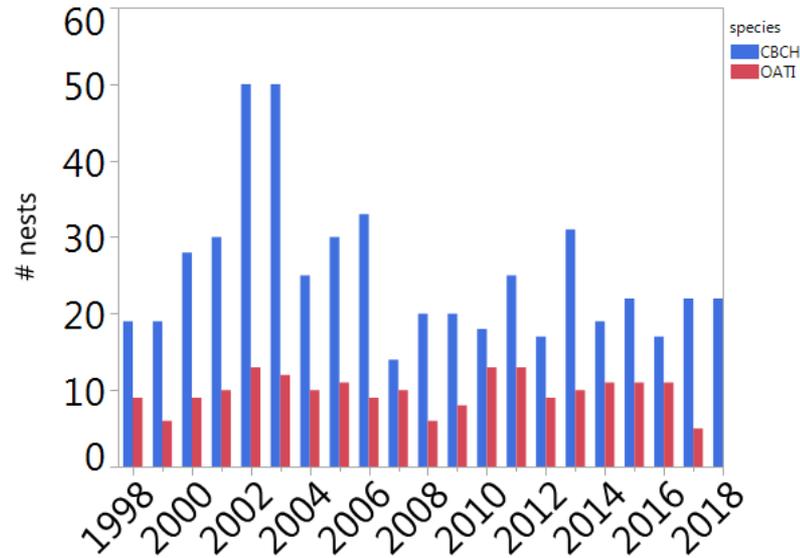
HERONRY NESTING IS VARIABLE OVER TIME

After a strong decline in 2007-2008, Great Egrets, Great Blue Herons, and Double-crested Cormorants moved from their old site near Rookery Pond to the Seal Bend portion of the Elkhorn Slough Reserve. Herons are quite stable over time; egrets and cormorants have had relatively low numbers in past years.

[See http://www.elkhornslough.org/research/bird_rookery.htm for more information]



CAVITY-NESTING BIRDS IN OAK WOODLANDS VARY IN REPRODUCTION ACROSS YEARS



Cavity nesting birds, especially Chestnut-backed Chickadees (CBCH) and Oak Titmice (OATI) use some of the 150 nestboxes on Elkhorn Reserve. Numbers of nesting pairs and fledging success show considerable variation over time, but no long-term trends

[For more information, see http://www.elkhornslough.org/research/bird_nestbox.htm]

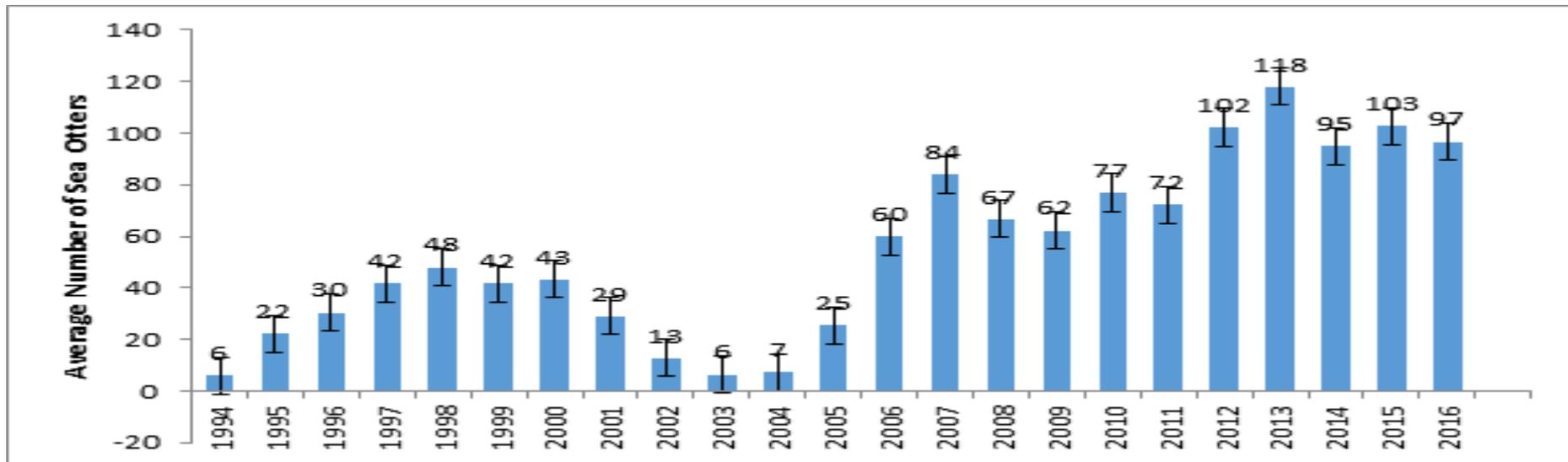


SEA OTTERS NUMBERS IN ELKHORN SLOUGH HAVE INCREASED SINCE 1990S

The number of sea otters in Elkhorn Slough has fluctuated since they first arrived in the 1990s, but has generally increased until recently. Long term monitoring may provide insights into the drivers of otter movements into new areas.



[See http://www.elkhornslough.org/sloughlife/mammals/sea_otter.htm for more information]



OTTER NUMBERS IN ELKHORN SLOUGH PROPER HAVE DROPPED BUT TOTALS HAVE REMAINED CONSTANT.

There are fewer sea otters in Elkhorn Slough (upstream of the Highway 1 bridge) since the peak year of 2014, but total numbers including the Harbor have remained constant.* This may be an indicator that the slough has reached carrying capacity.



* Apparent increase in Slough Counts (including harbor) is due to improved harbor monitoring.

THE NUMBER OF SEA OTTERS IN ELKHORN SLOUGH ALSO VARIES THROUGHOUT THE YEAR

The number of sea otters in the slough and the harbor varies with the seasons, peaking in the summer. Females stay within the slough. Males move between the harbor, the bay and the slough.

[See http://www.elkhornslough.org/sloughlife/mammals/sea_otter.htm for more information]

