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.

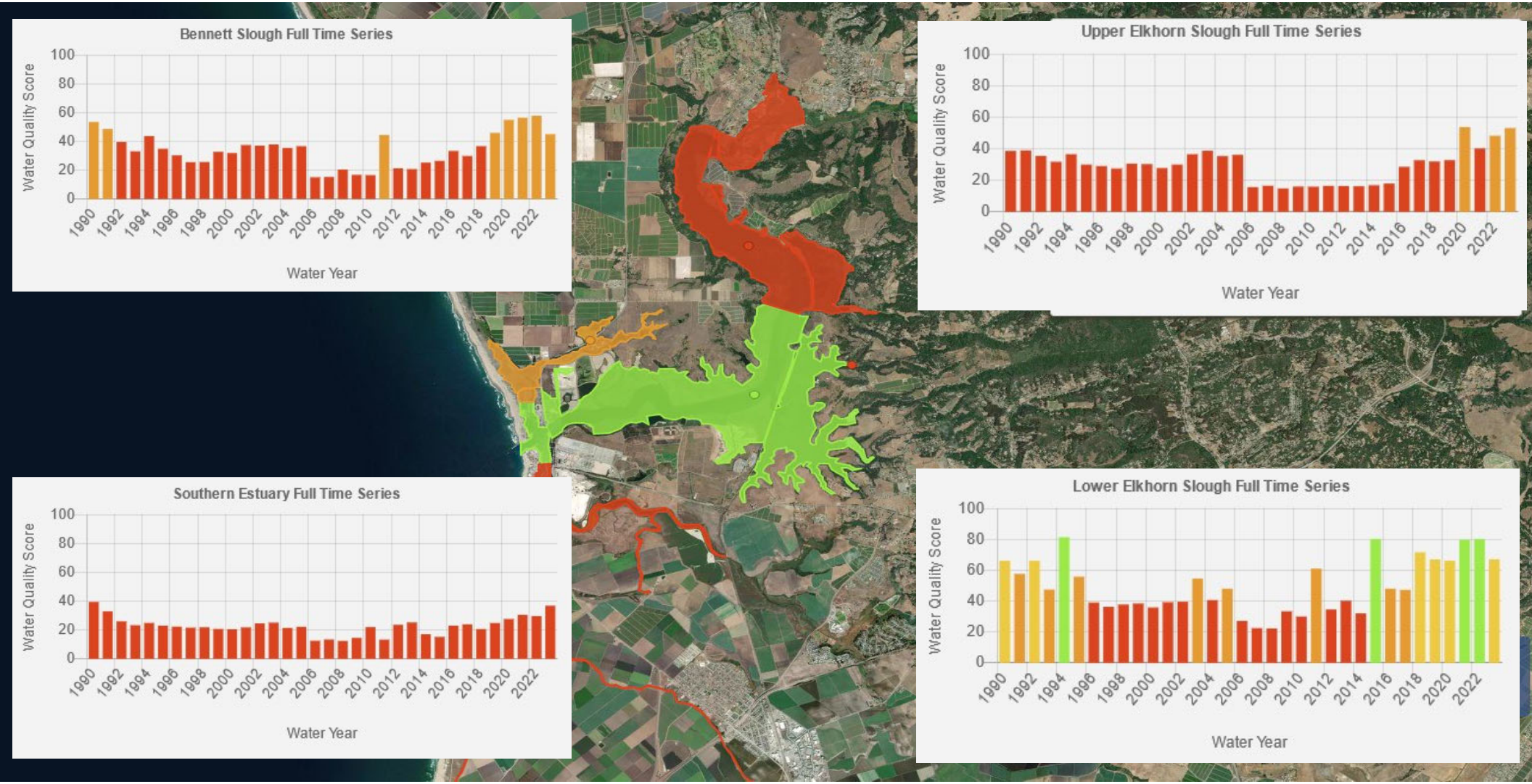
This report provides highlights of temporal trends in key indicators monitored by the Elkhorn Slough National Estuarine Research Reserve, owned and operated by the California Department of Fish and Wildlife in partnership with the National Oceanic and Atmospheric Administration and the non-profit Elkhorn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

WATER QUALITY REMAINS POOR IN MOST REGIONS BUT IS IMPROVING RECENT YEARS

Scores are based on exceedances of thresholds of nine parameters over one water year period. High scores indicate healthier water quality. [See interactive webpage at https://water.elkhornslough.org/]

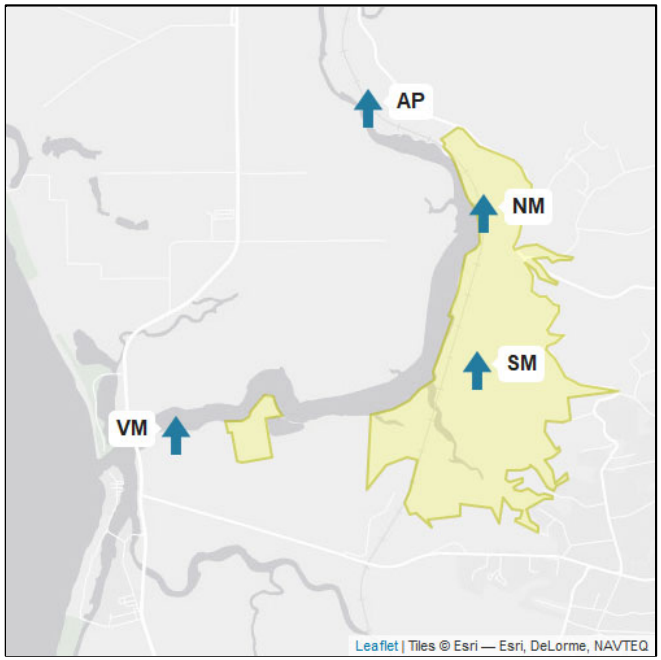


TEMPERATURE AND OXYGEN LEVELS HAVE INCREASED OVER PAST DECADE

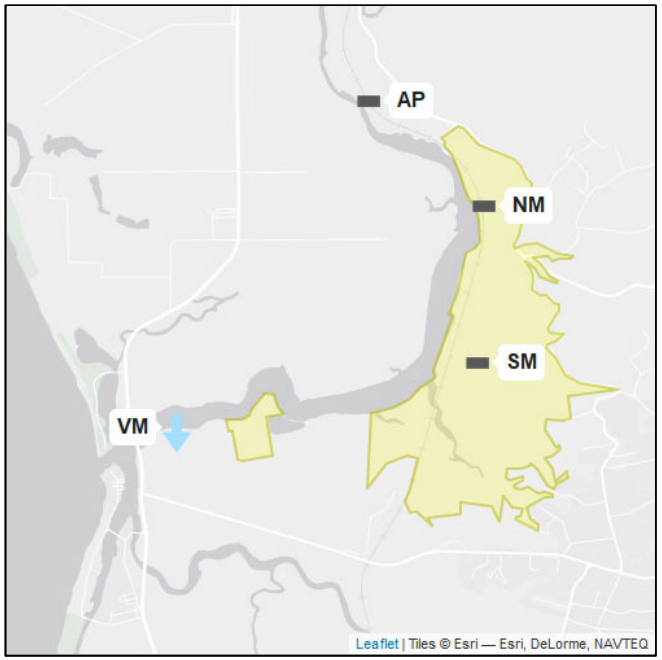
Temporal trends over the past decade were analyzed from permanent stations collecting water quality data every 15 minutes. Temperature and oxygen increased in the two sites located on the Reserve.

[See http://cdmo.baruch.sc.edu/ for this and all similar data collected across the NERRs]

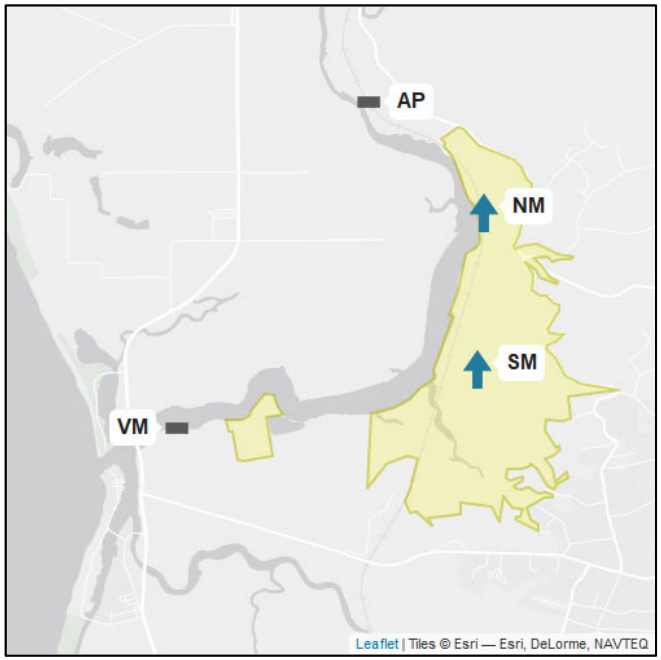
Temperature is increasing in all of the four sites



pH is decreasing in one site and unchanged at the other three sites



Dissolved oxygen is increasing in two sites and unchanged at the other two sites

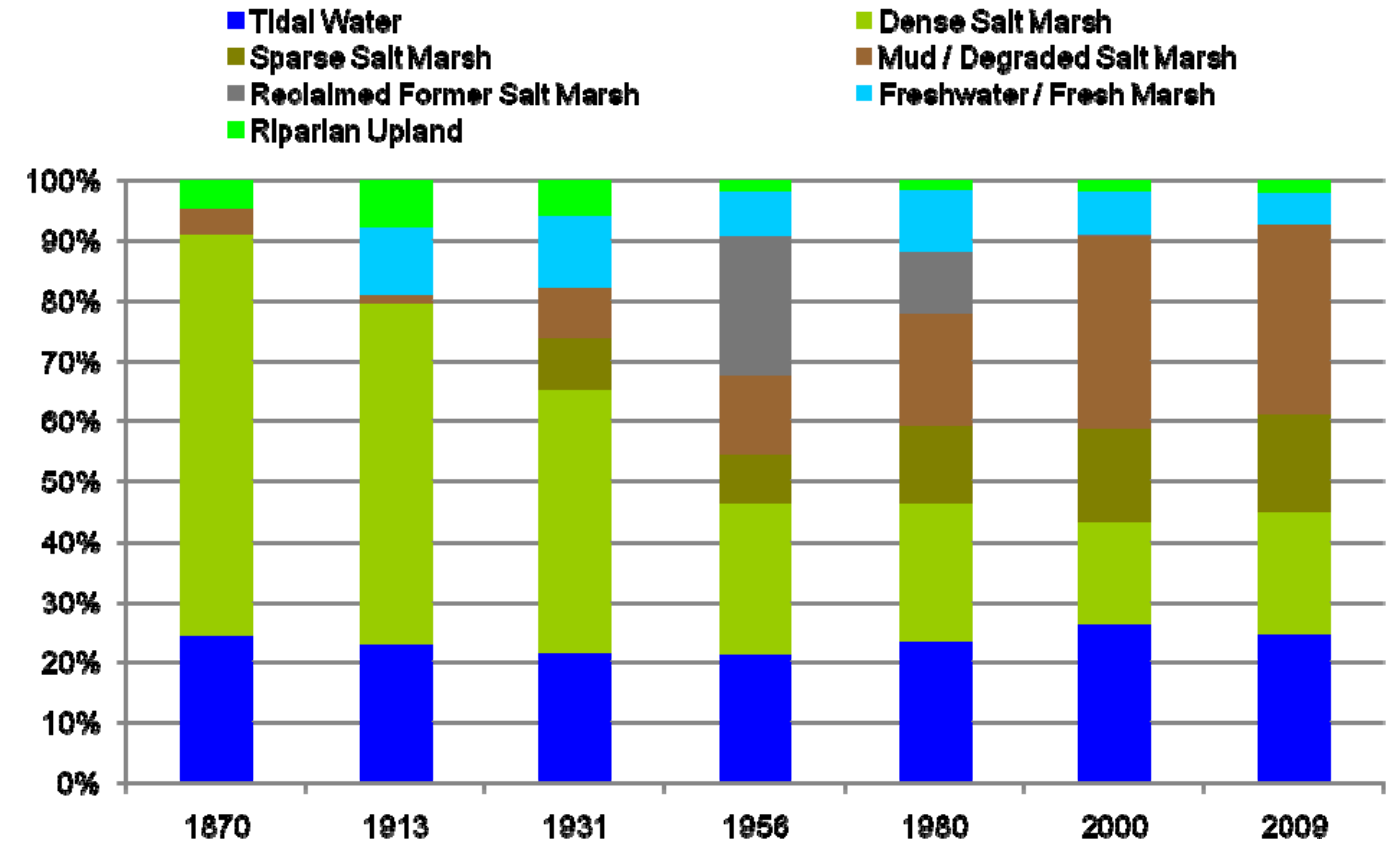


VM = Vierra; SM = South Marsh, NM = North Marsh, AP = North Azevedo Pond; ESNERR sites

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 recently. Marsh loss has multiple causes, including human changes to tidal exchange and sediment supply.

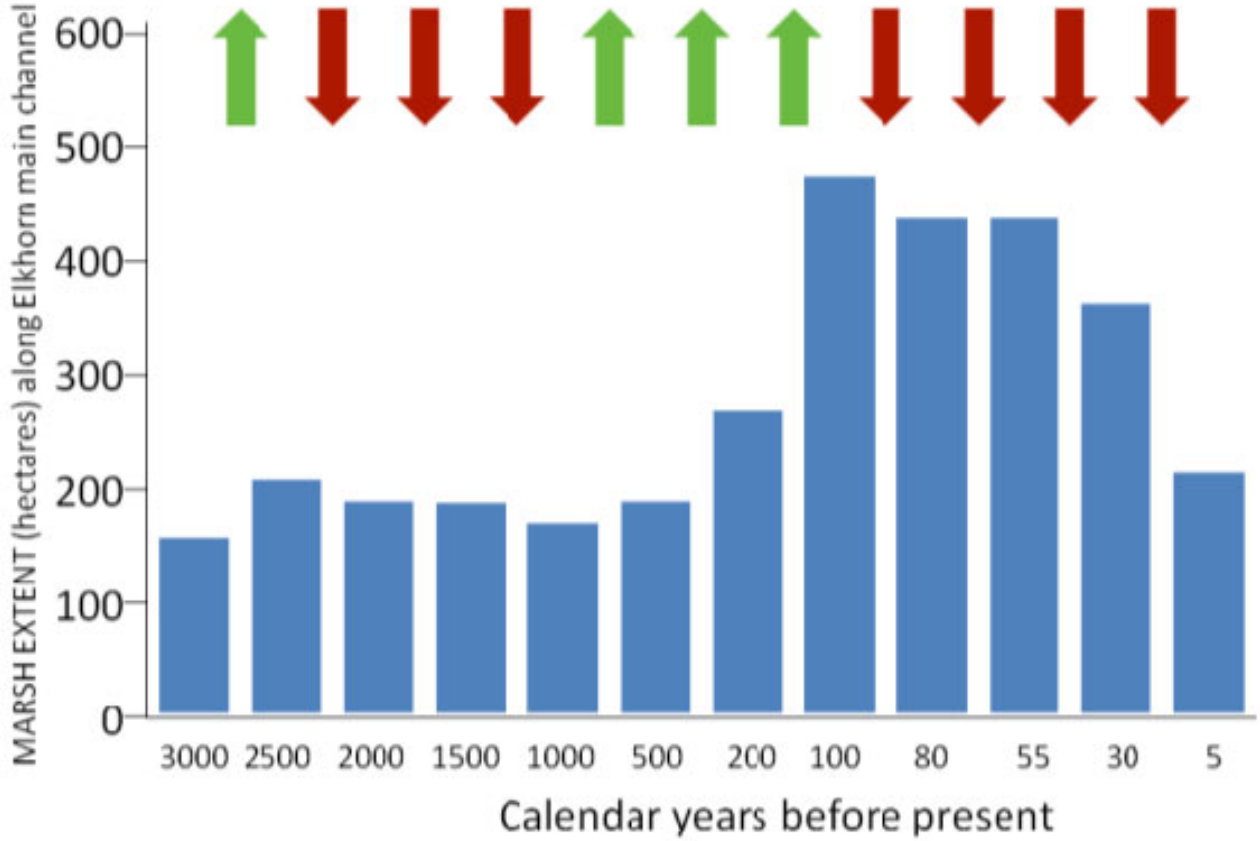
[See http://www.elkhornslough.org/research/conserv_marsh.htm for more information]



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 following European colonization, but this has been followed by a sharp decline.

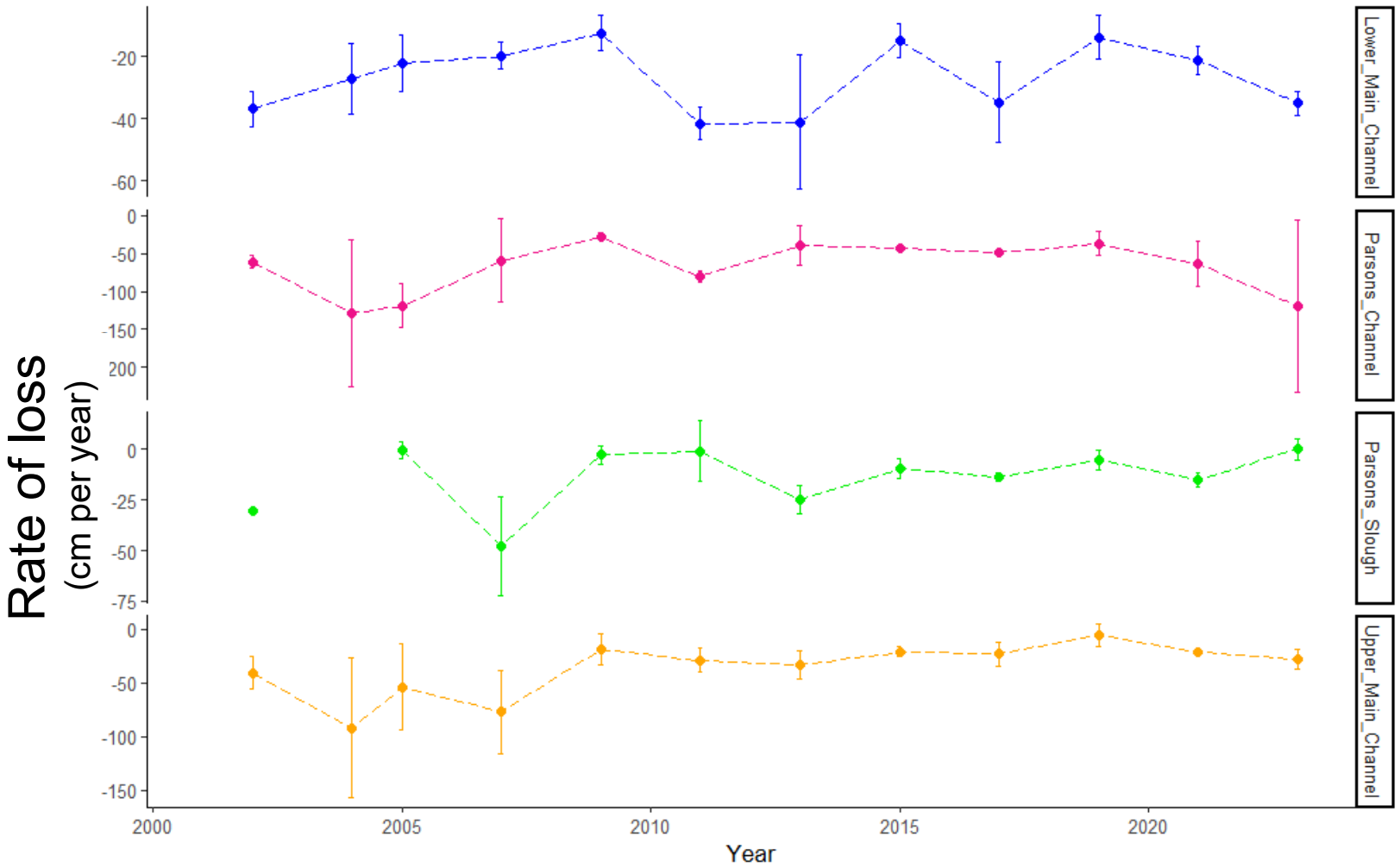
[See http://www.elkhornslough.org/research/conserv_marsh.htm for more information]



CHANNEL BANKS CONTINUE TO ERODE

Along the channels of Elkhorn Slough, bank edges continue to erode, with no clear increase or decrease over time. Erosion rates are affected by algal wrack, wind waves and tidal currents.

[See http://www.elkhornslough.org/research/conserv_erosion.htm for more information on this monitoring program conducted in partnership with the Monterey Bay National Marine Sanctuary]

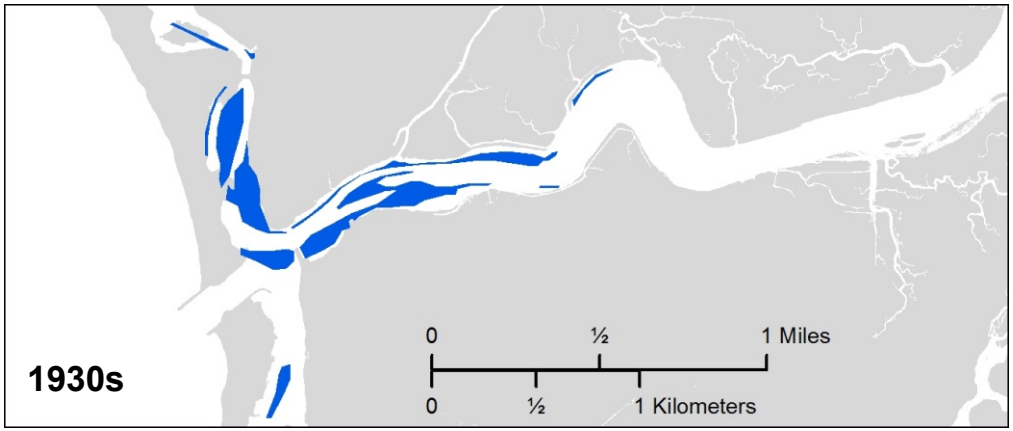


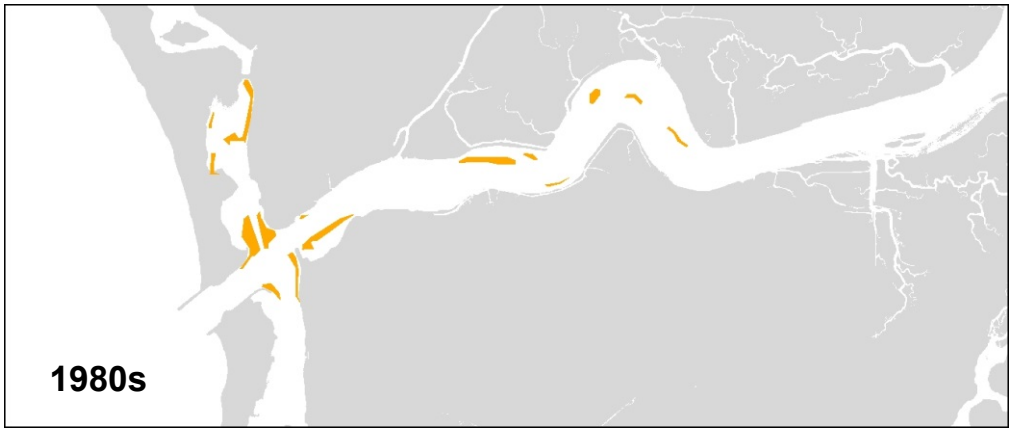
Geographic_Category
- Lower_Main_Channel
- Parsons_Channel
- Parsons_Slough
- Upper_Main_Channel

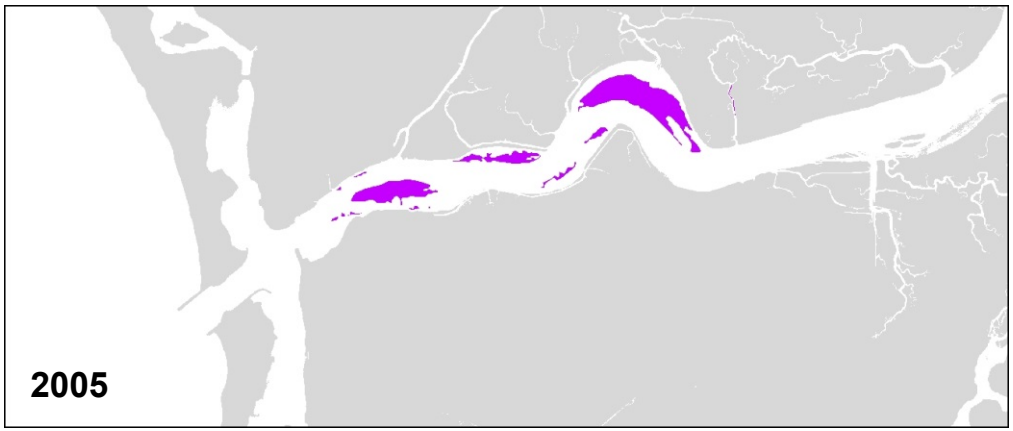
EELGRASS HAS RECOVERED IN PAST DECADES

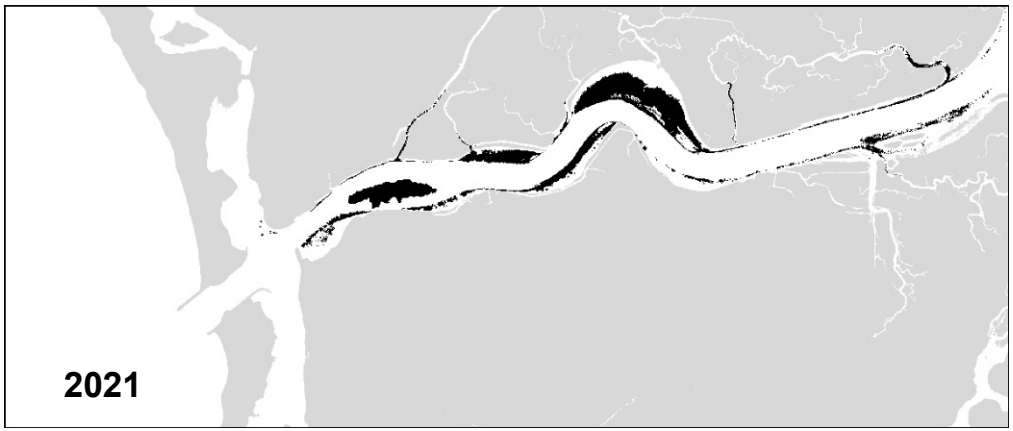
Analysis of aerial photos reveals dramatic loss of eelgrass beds in harbor area and lower Elkhorn Slough, followed by a period of recovery in the 1990s to the present.

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



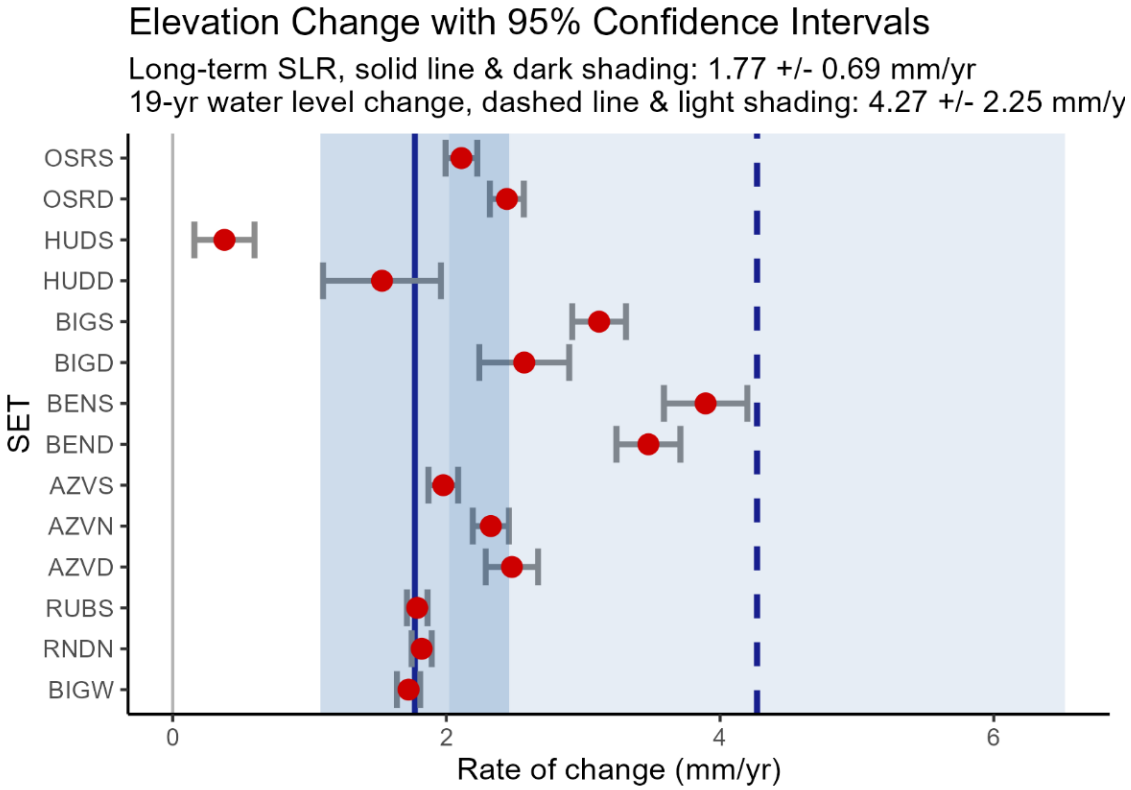


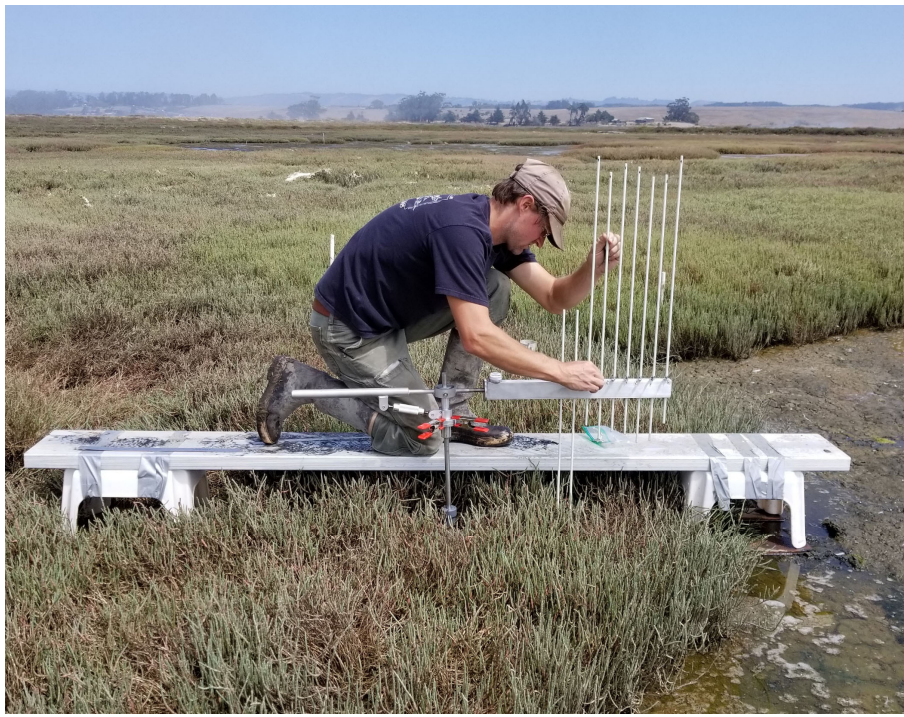




MARSHES ARE NOT TRACKING RECENTLY ACCELERATED SEA LEVEL RISE

Surface Elevation Tables (SETs) measure precise changes in the elevation of the marsh surface. Averaged together, results show the marsh is keeping pace with the long-term sea level rise rate (since 1973), but not with the recent 19-year rate (since 2005).





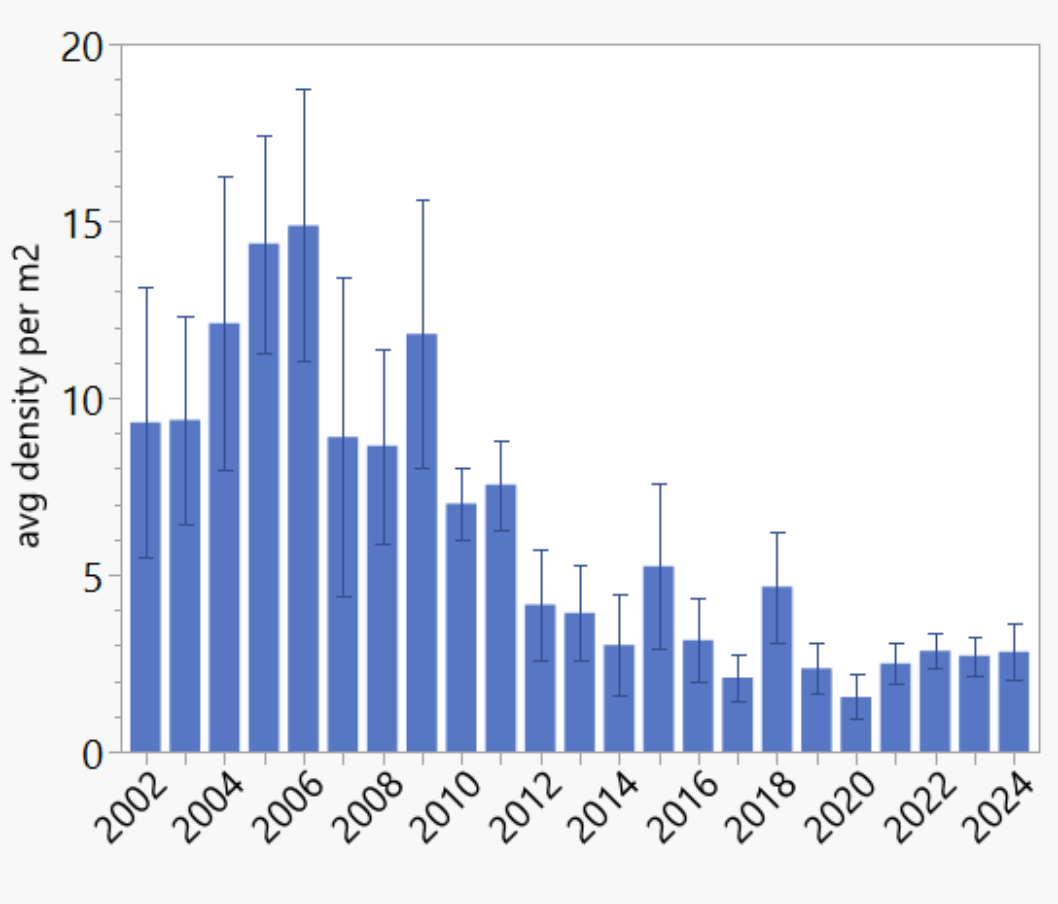
MARSH ELEVATION GAIN
(1.82 mm/yr)

vs.

SEA LEVEL RISE
(1.77 mm/yr since 1973;
4.27 mm/yr since 2005)

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]



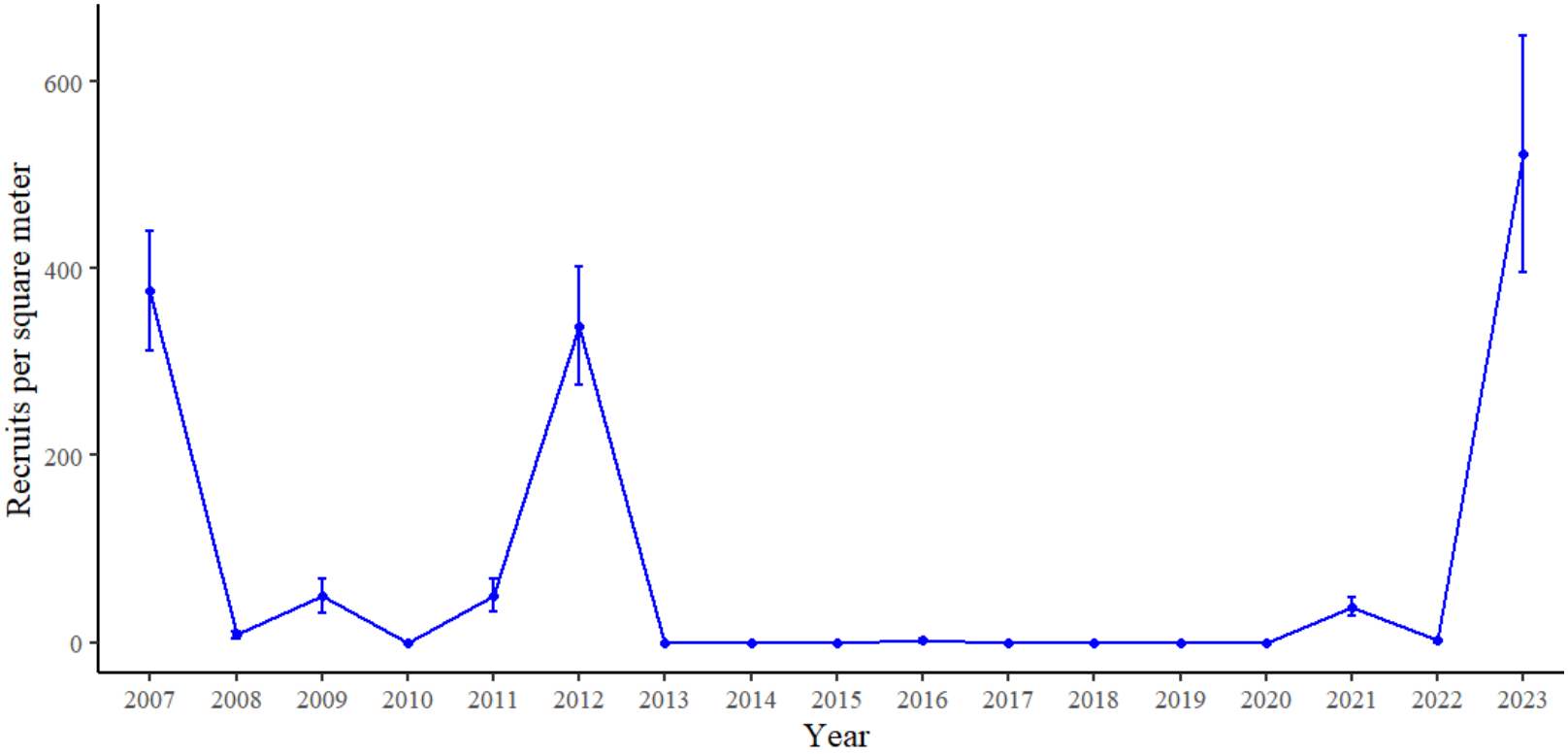
Fat innkeeper

Gaper clam

NATIVE OYSTERS REPRODUCING AGAIN AFTER MANY YEARS OF FAILURE

Between 2013 and 2022, there was virtually no reproduction in the estuary. In 2023 there was spectacular recruitment, likely due to the order-of-magnitude increase in adult population size from conservation aquaculture in partnership with MLML.

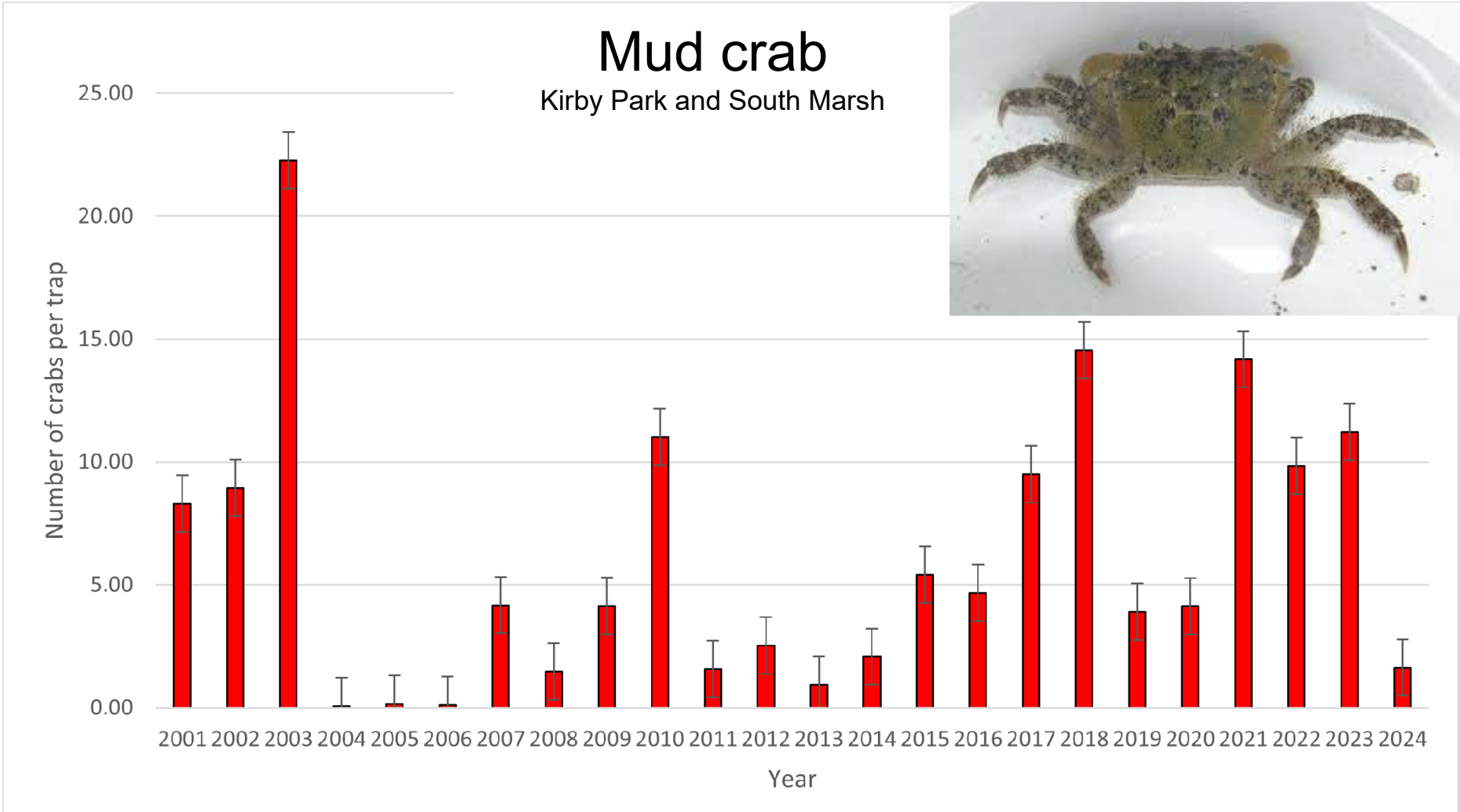
[See http://www.elkhornslough.org/research/conserv_oysters.htm for more information]



MUD CRAB NUMBERS ARE HIGHLY VARIABLE

We monitor crabs annually at two sites.

Abundance of native mud crab is generally high and variable.
In 2024 native mud crab abundance was very low.

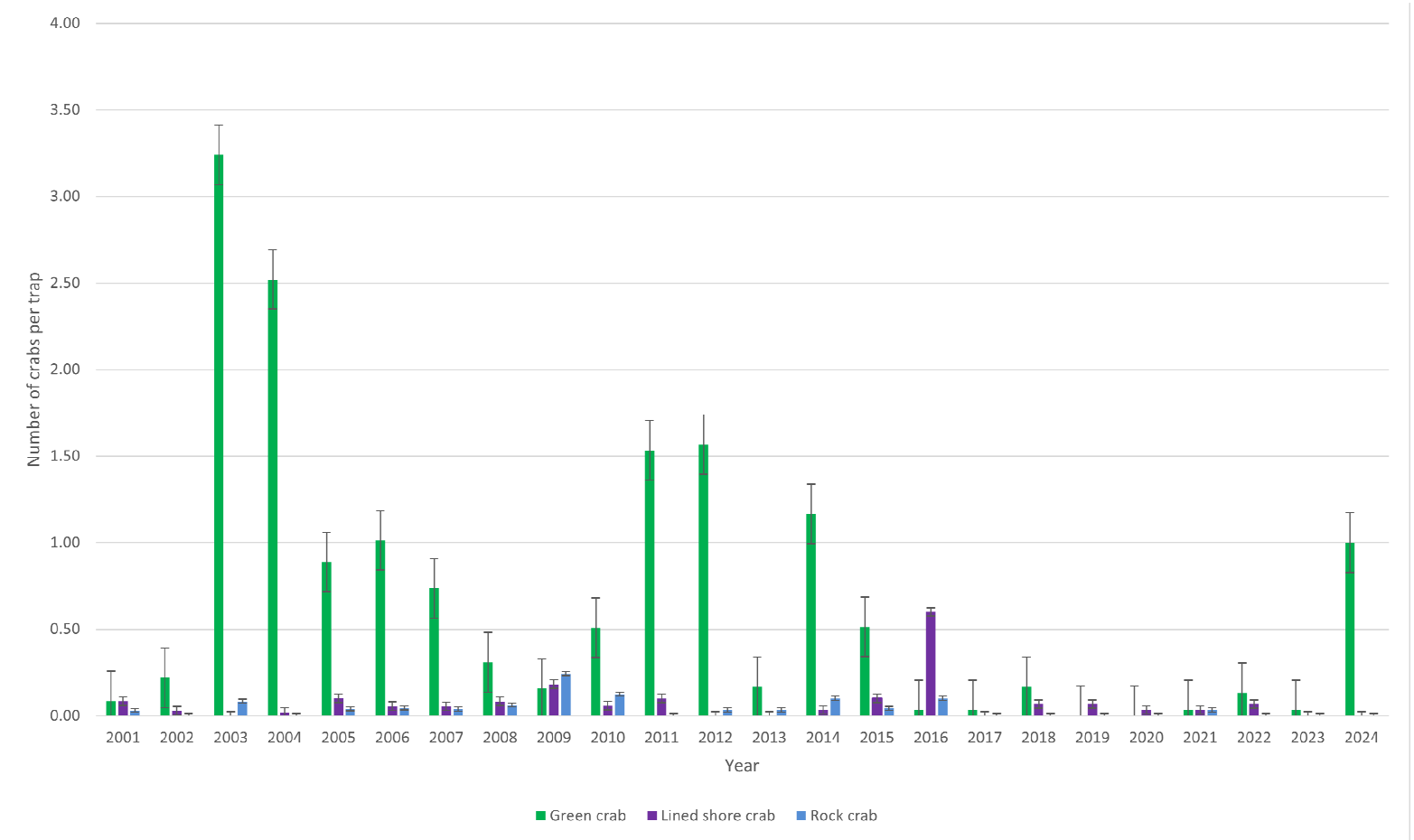


GREEN CRAB NUMBERS HAVE MOSTLY REMAINED LOW FOR PAST DECADE

Abundance of non-native green crab is often about ten-fold lower than mud crab seen in the previous slide.

In 2024, green crab abundance was the highest in a decade

[See https://elkhornslough.org/reserve/research/invertebrate-montoring/ for more info]



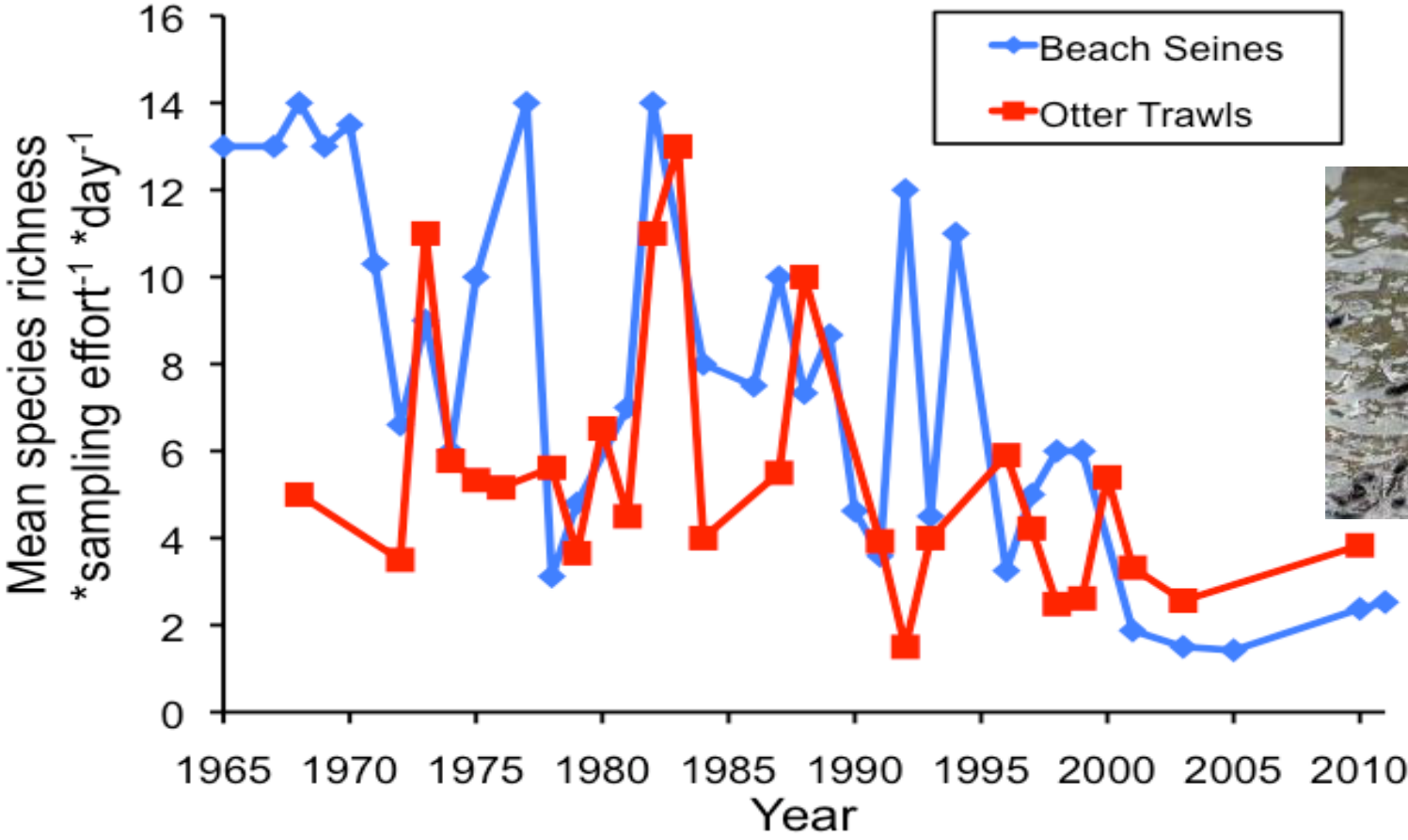
European green crab

Lined shore crab

Rock crab

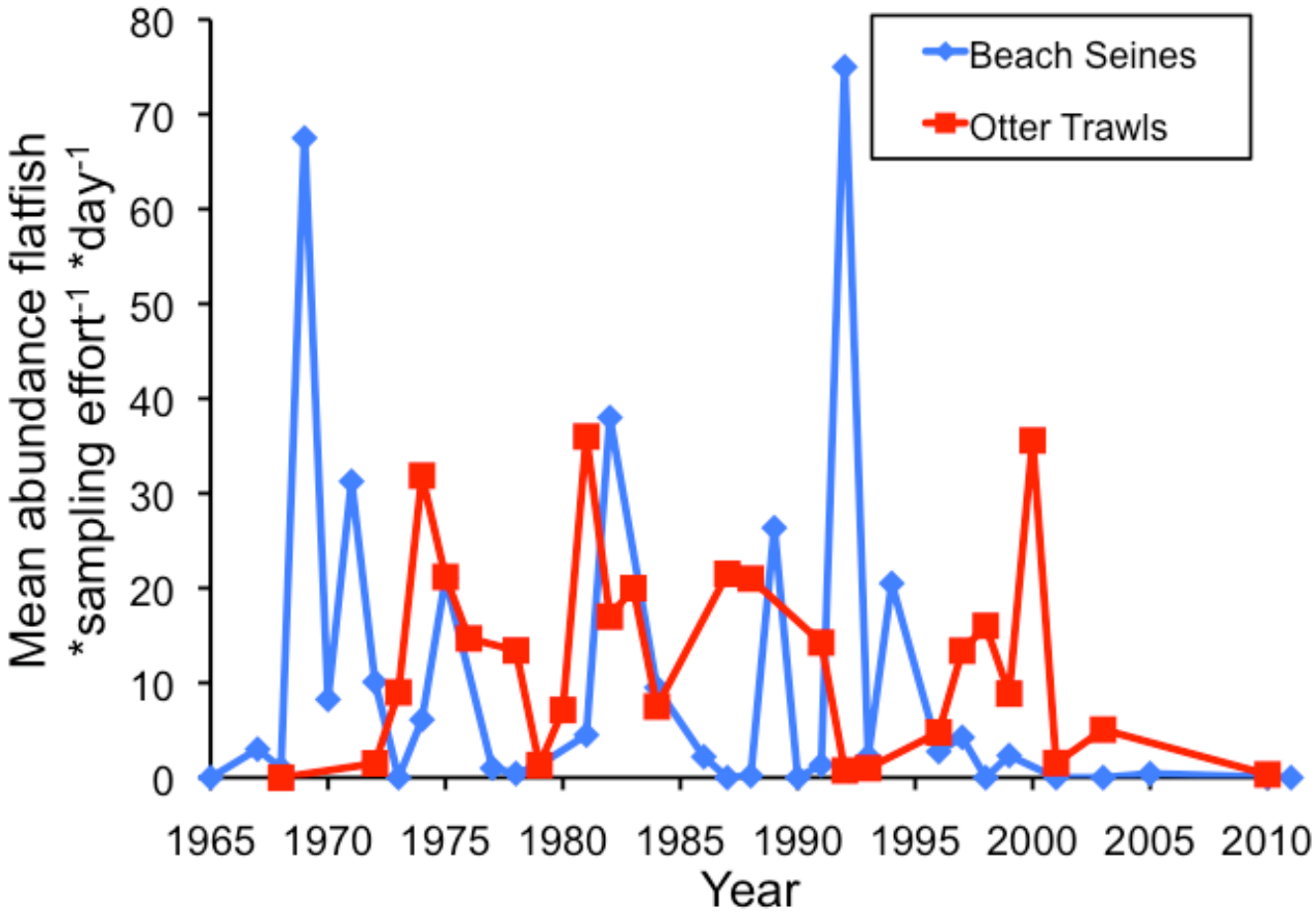
FISH DIVERSITY HAS DECLINED IN ELKHORN SLOUGH OVER THE PAST DECADES

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.]



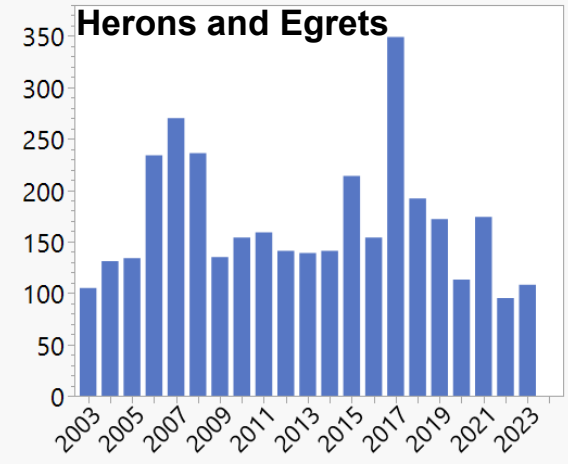
FLATFISH ABUNDANCE HAS DECLINED IN ELKHORN SLOUGH OVER THE PAST DECADES

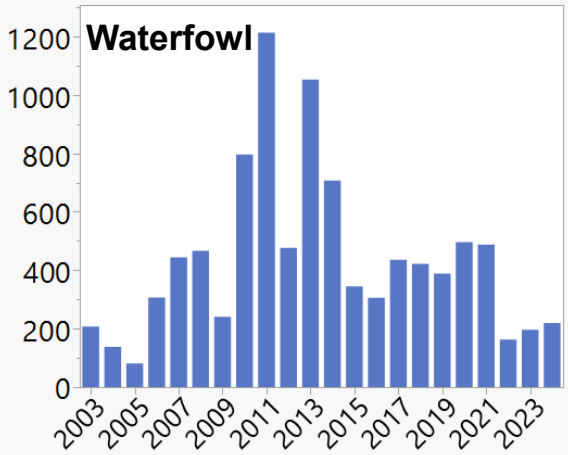
Both beach seines and otter trawls reveal a decrease in average abundance of flatfish in the Elkhorn Slough main channel over time. Numbers have been especially low in the past decade.[Data from multiple sources made available by the Monterey Bay National Marine Sanctuary's Integrated Monitoring Network,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

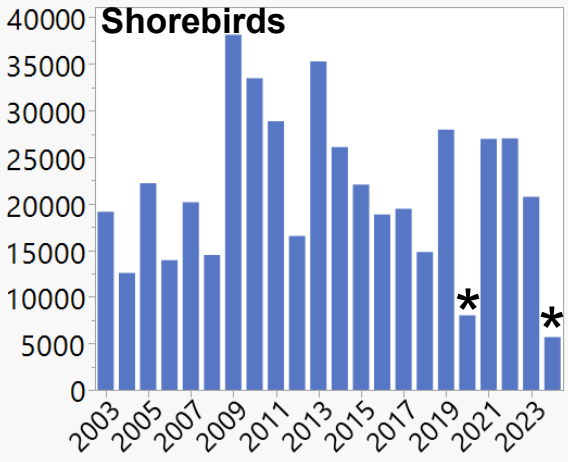



S. Anderson

WATERBIRDS ARE ABUNDANT IN THE ESTUARY







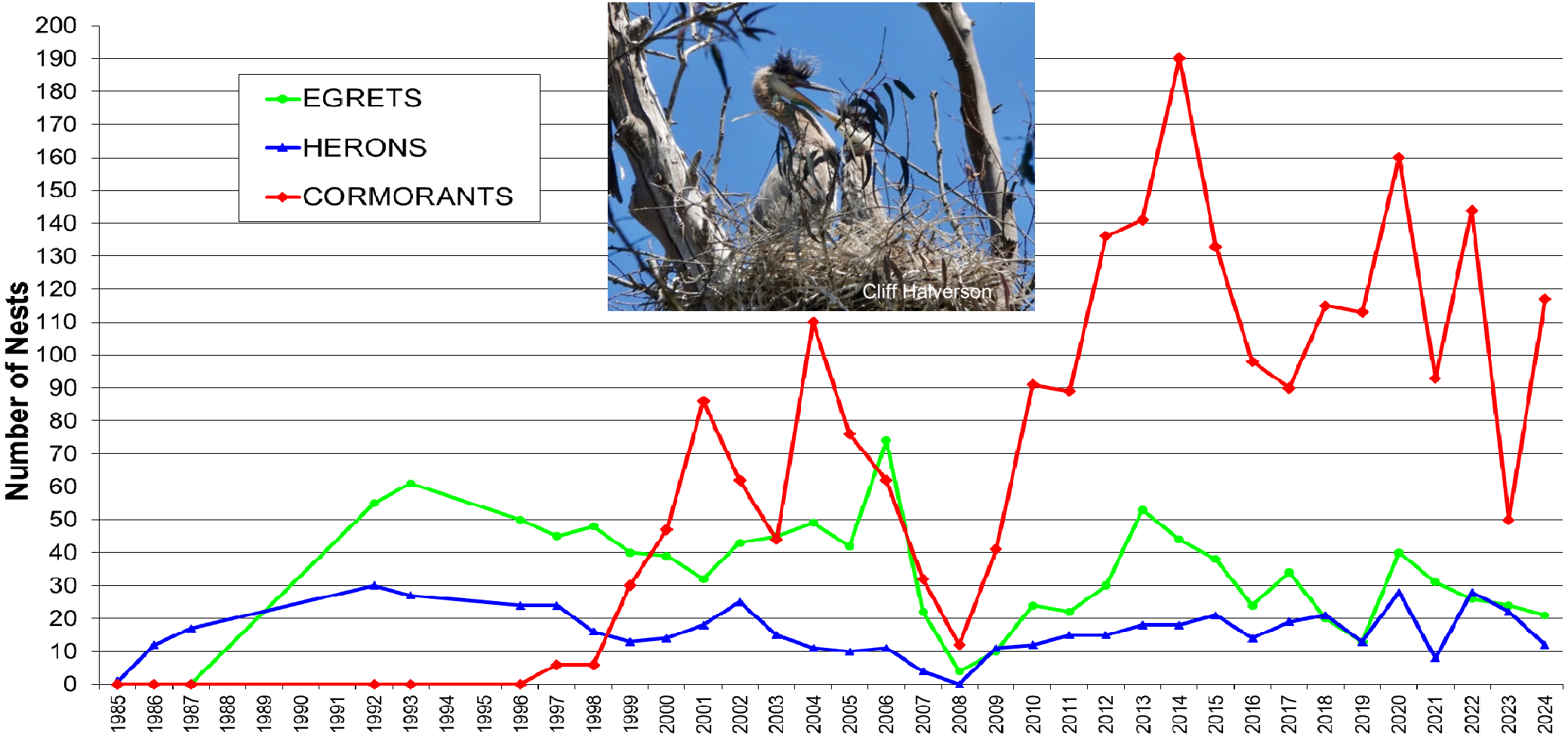
Thousands of shorebirds and hundreds of waterfowl and waders are detected in annual bird surveys. There is considerable interannual variation in abundance, not synchronized between bird groups, and no clear trends.

*Main Channel not surveyed in 2020 or 2024, so total shorebird counts low and not representative for those years.

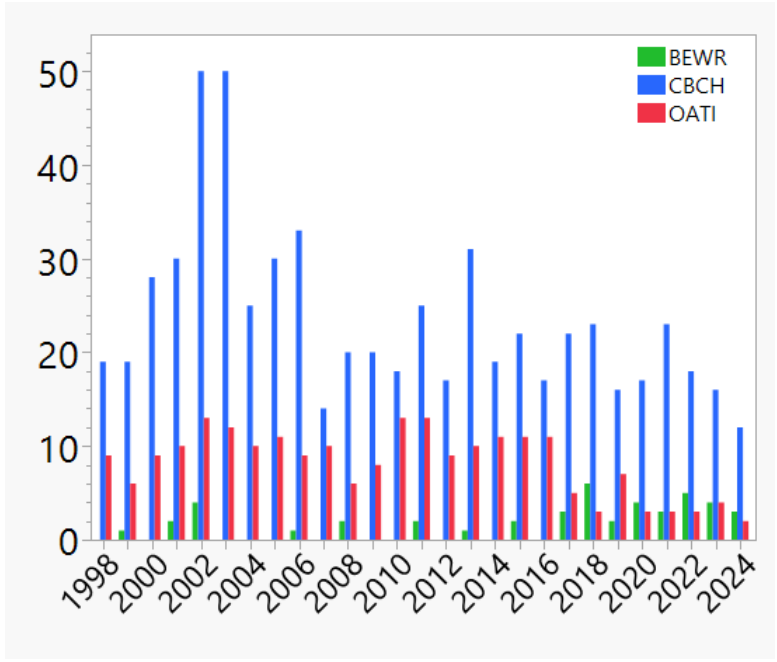
[http://library.elkhornslough.org/attachments/Fork_2014_Shorebirds_Waterfowl_And_Waders.pdf for more information on this monitoring program conducted in partnership with Moss Landing Marine Laboratories]

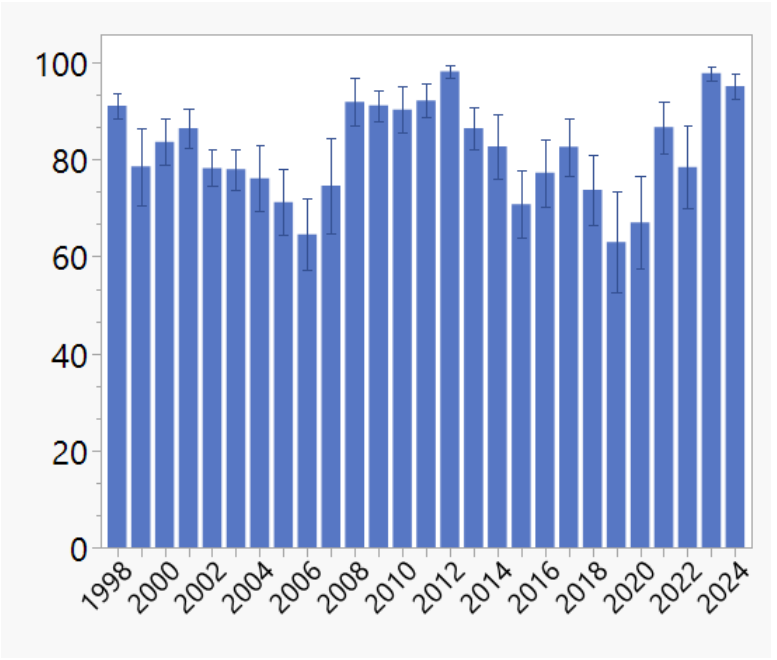
HERONRY NESTING IS VARIABLE OVER TIME

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 variable numbers of nests across years.



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



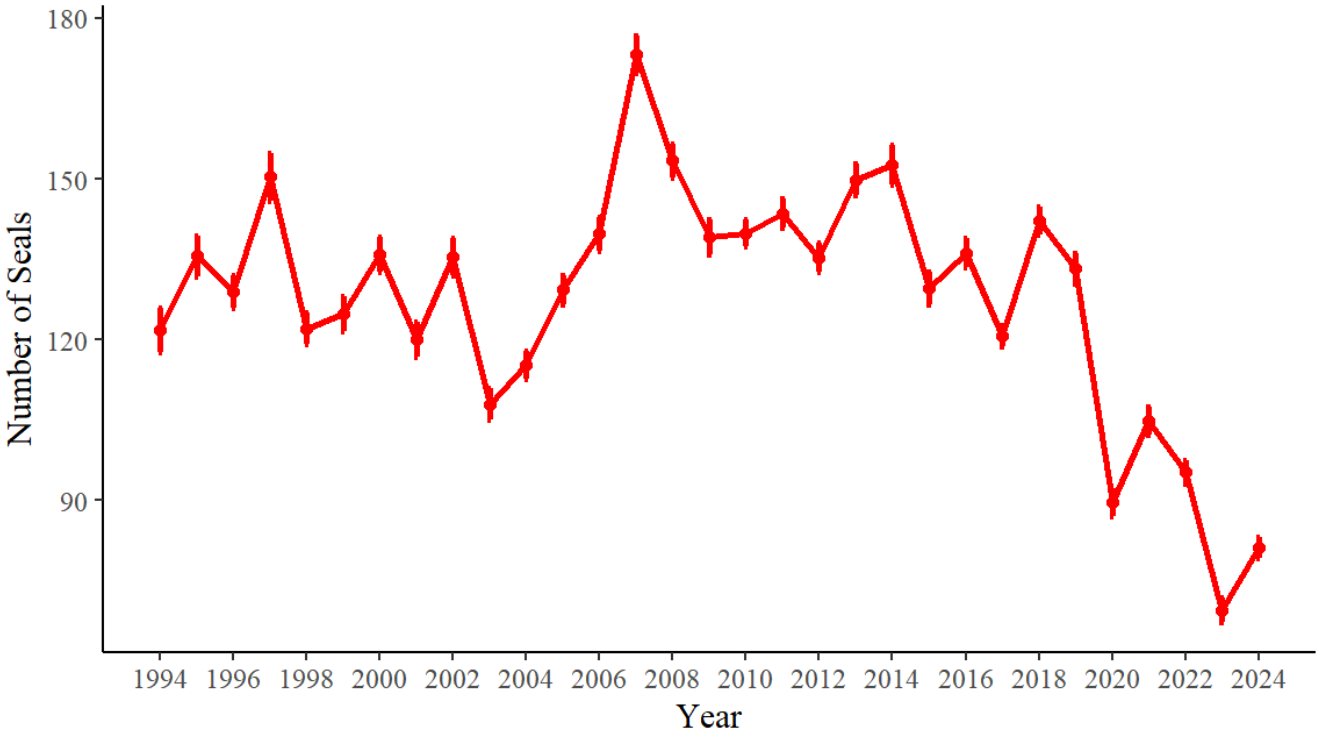


Cavity nesting birds, especially Chestnut-backed Chickadee (CBCH), Oak Titmouse (OATI) and Bewick's Wren (BEWR) use some of the 150 nestboxes on Elkhorn Reserve. Numbers of nesting pairs and fledging success show considerable variation over time, but no long-term trends

HARBOR SEAL NUMBERS VARIABLE OVER TIME IN ESTUARY, WITH RECENT DECREASE

Long-term trends revealed by community monitoring by the Elkhorn Slough Safari show high variation among years, with record highs in 2008 and record lows in past few years. On some days, over 400 seals are documented in the estuary.

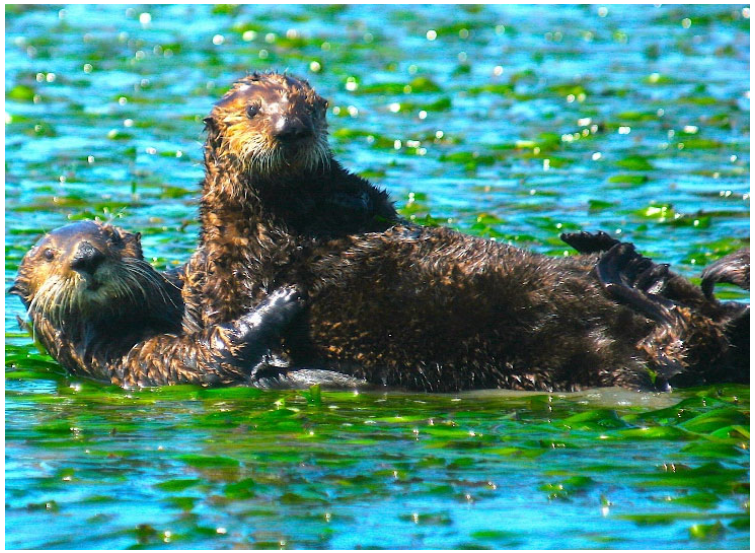
[Data collected by Elkhorn Slough Safari provided generously by Captains Yohn Gideon and Joe Mancino and entered by ESNERR volunteer Jeff Wagner. For more information see https://elkhornslough.org/reserve/research/reserve-otter-monitoring-project/]



SEA OTTER NUMBERS HIGH IN ELKHORN SLOUGH FOR THE PAST 15 YEARS

Long-term trends revealed by community monitoring by the Elkhorn Slough Safari show some variation among years, but generally high numbers of otters.

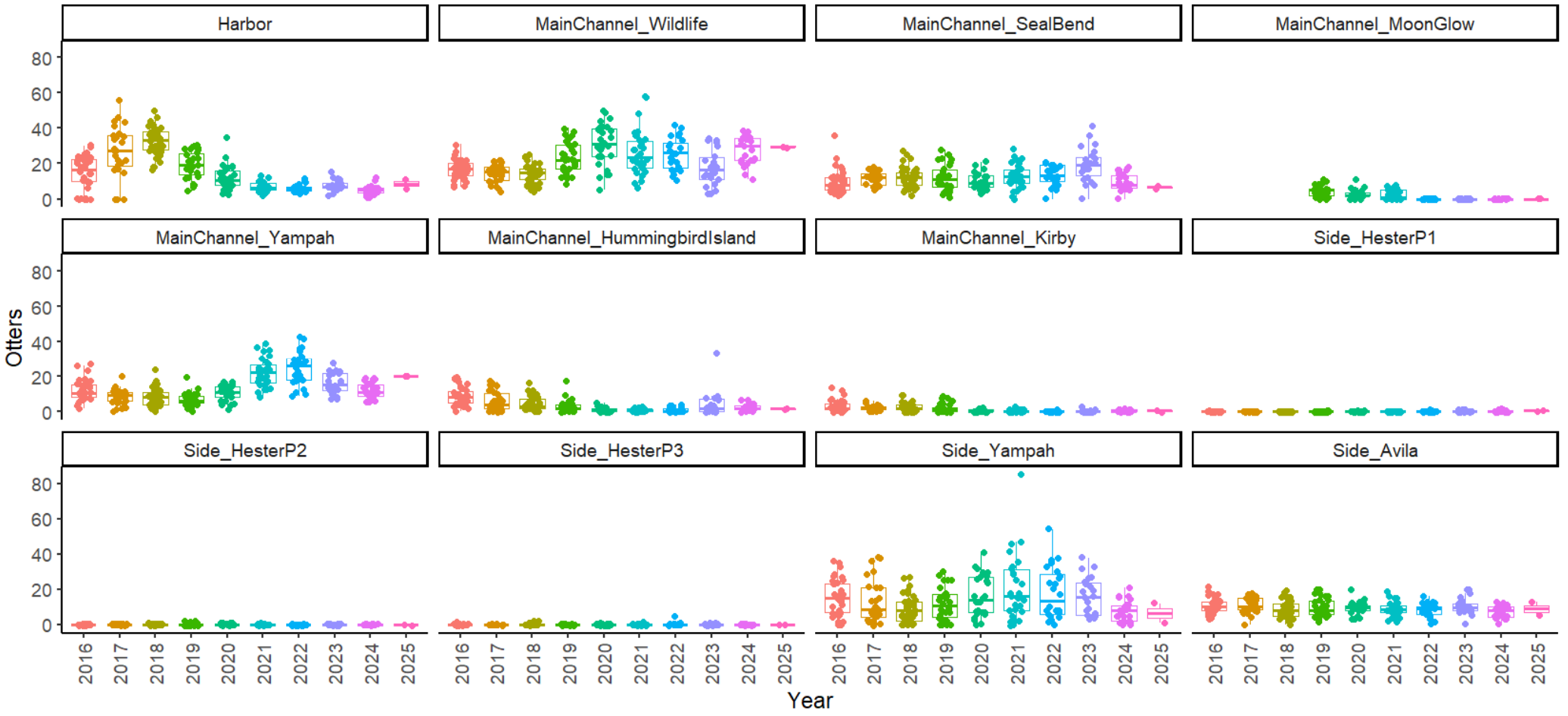
[Data collected by Elkhorn Slough Safari provided generously by Captains Yohn Gideon and Joe Mancino and entered by ESNERR volunteer Jeff Wagner. For more information see https://elkhornslough.org/reserve/research/reserve-otter-monitoring-project/ , and a recent publication of these data https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.4300]



OTTER ABUNDANCE TRENDS VARY BY SITE

Consistent simultaneous monitoring at a dozen sites by Reserve volunteers shows contrasting patterns. Use of harbor by otters has decreased while use of main channel in lower area near wildlife platform and near Yampah has increased.

[For more information see https://elkhornslough.org/reserve/research/reserve-otter-monitoring-project/]



OTTER NUMBERS VARY BY SITE AND BY SEASON

Contrasting patterns over time and season (1=first quarter of year, 2= second quarter, etc.) at three of the twelve monitoring sites. Otter movement to different Slough regions accounts for increases at one site matched by decreases at another.

[For more information see https://elkhornslough.org/reserve/research/reserve-otter-monitoring-project/ , and a recent publication of these data https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/ecs2.4300]