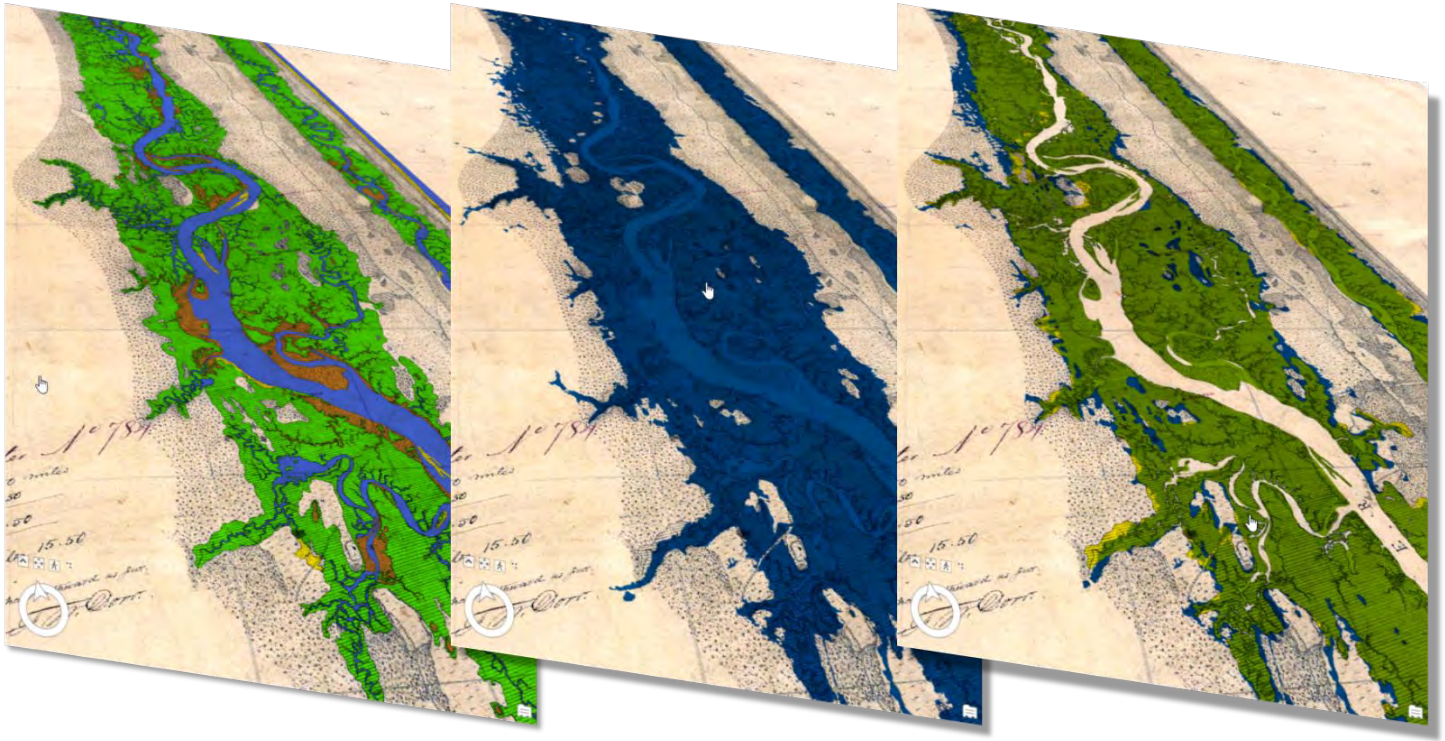
ESTUARIES PAST, PRESENT AND FUTURE:

using elevations and historical maps to characterize estuarine habitats across 30 National Estuarine Research Reserves



Why map estuaries?

How?

What did we learn?

ESTUARIES ARE TREASURES

nurseries for fish, carbon storage, shoreline protection, recreational and cultural importance, intrinsic value

ESTUARIES MERIT CONSERVATION ACTION

but what exactly should we protect and restore?

Wildlife in our Wetlands, NERR synthesis (Sapelo Island)

BOUNDARIES CAN BE MURKY

full estuary extent often unclear

Brackish tidal swamp in Oregon,
Photo: L.S. Brophy, CC BY-NC

SHIFTING BASELINES PROBLEMS

today's estuary may be much smaller than yesterday's

ESTUARY HABITAT CHANGE

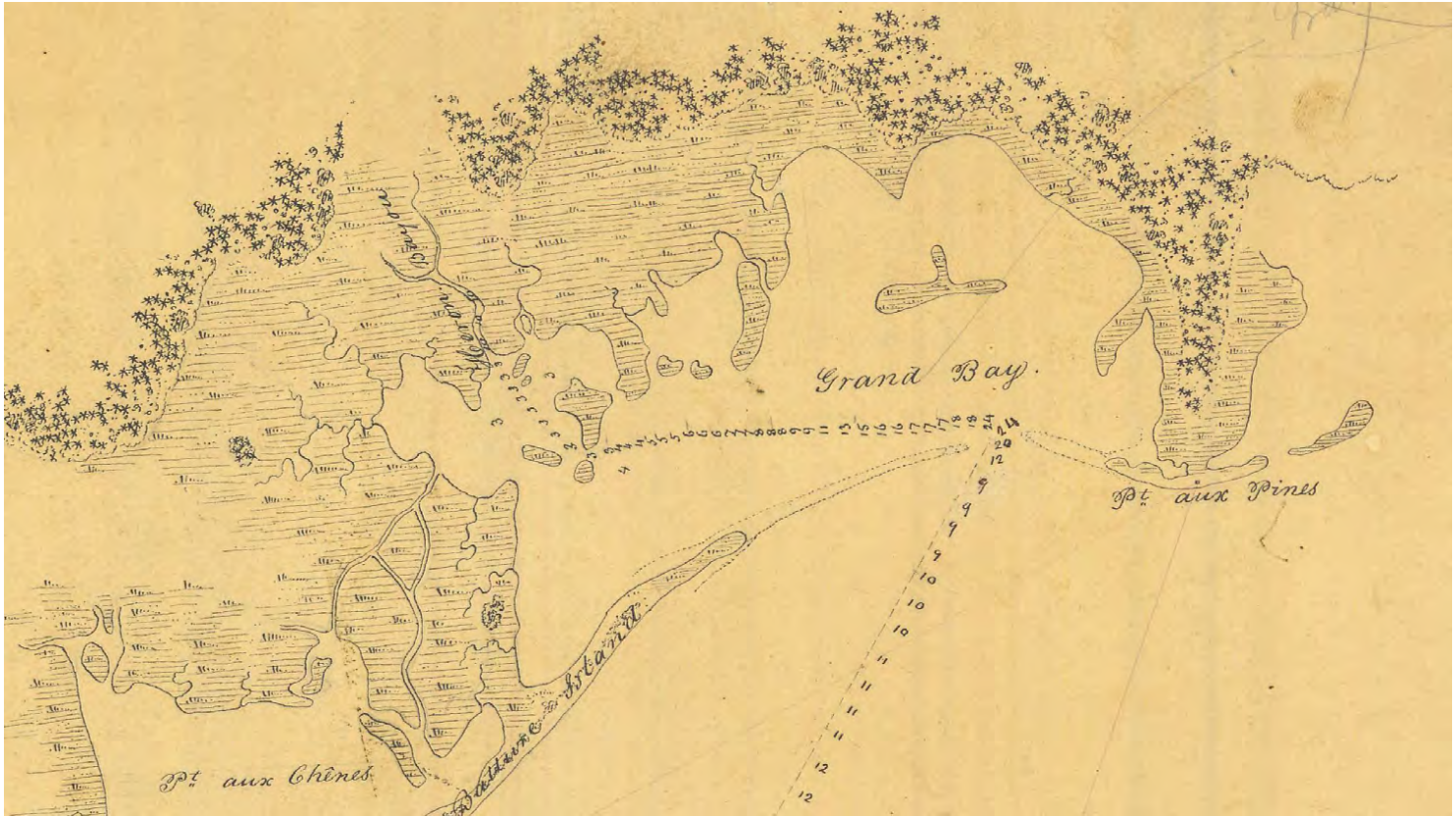
the most altered ecosystems on earth

TRAJECTORIES OF CHANGE

key to understand for sea-level rise adaptation

ESTUARY MAPPING GOALS

where our estuaries are, were, and could be

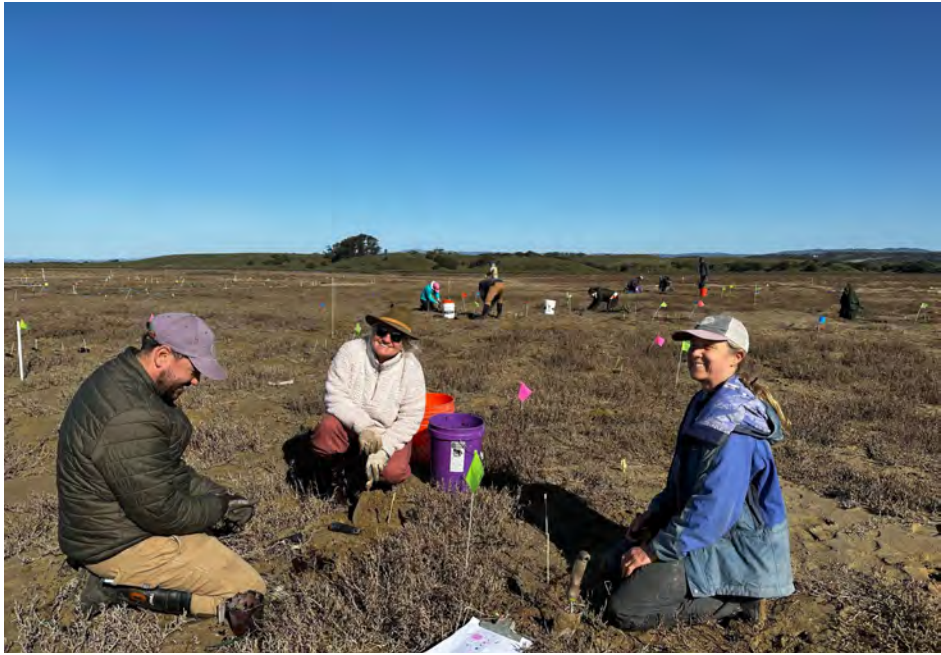


ENHANCE CONSERVATION PLANNING

- ★ improve protection by generating more accurate maps
- ★ detect currently disconnected parts of former estuary that could be reconnected in future

BUILD SUPPORT FOR RESTORATION AND ADAPTATION

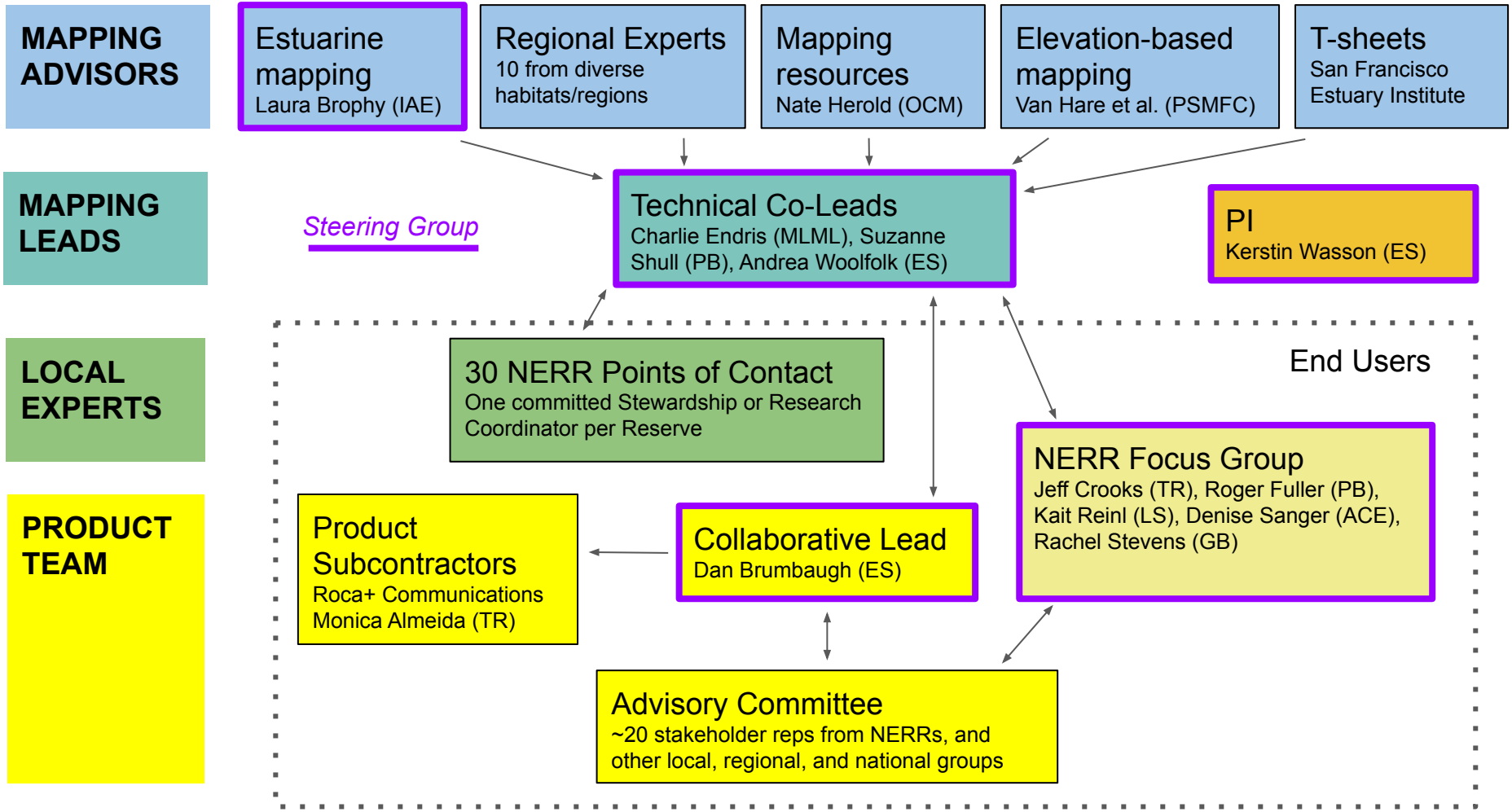
- ★ educate stakeholders about estuary dynamics
- ★ highlight restoration need and opportunities



Why map estuaries?

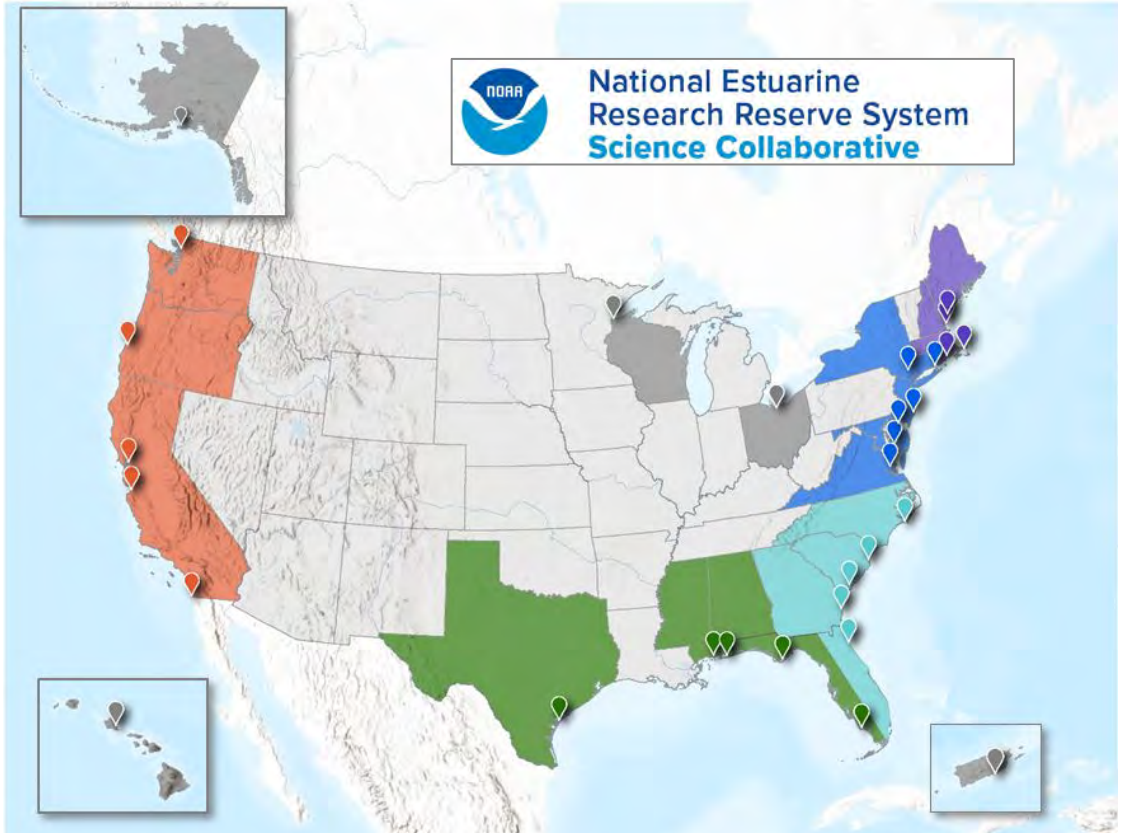
How?

What did we learn?


MAPPING ADVISORS
MAPPING LEADS
LOCAL EXPERTS
PRODUCT TEAM
Estuarine mapping
Laura Brophy (IAE)
Regional Experts
10 from diverse habitats/regions
Mapping resources
Nate Herold (OCM)
Elevation-based mapping
Van Hare et al. (PSMFC)
T-sheets
San Francisco Estuary Institute
Steering Group
Technical Co-Leads
Charlie Endris (MLML), Suzanne Shull (PB), Andrea Woolfolk (ES)
PI
Kerstin Wasson (ES)
End Users
30 NERR Points of Contact
One committed Stewardship or Research Coordinator per Reserve
NERR Focus Group
Jeff Crooks (TR), Roger Fuller (PB), Kait Reinl (LS), Denise Sanger (ACE), Rachel Stevens (GB)
Product Subcontractors
Roca+ Communications
Monica Almeida (TR)
Collaborative Lead
Dan Brumbaugh (ES)
Advisory Committee
~20 stakeholder reps from NERRs, and other local, regional, and national groups

NATIONAL MAPPING PROJECT

mapping estuaries at 30 NERRS

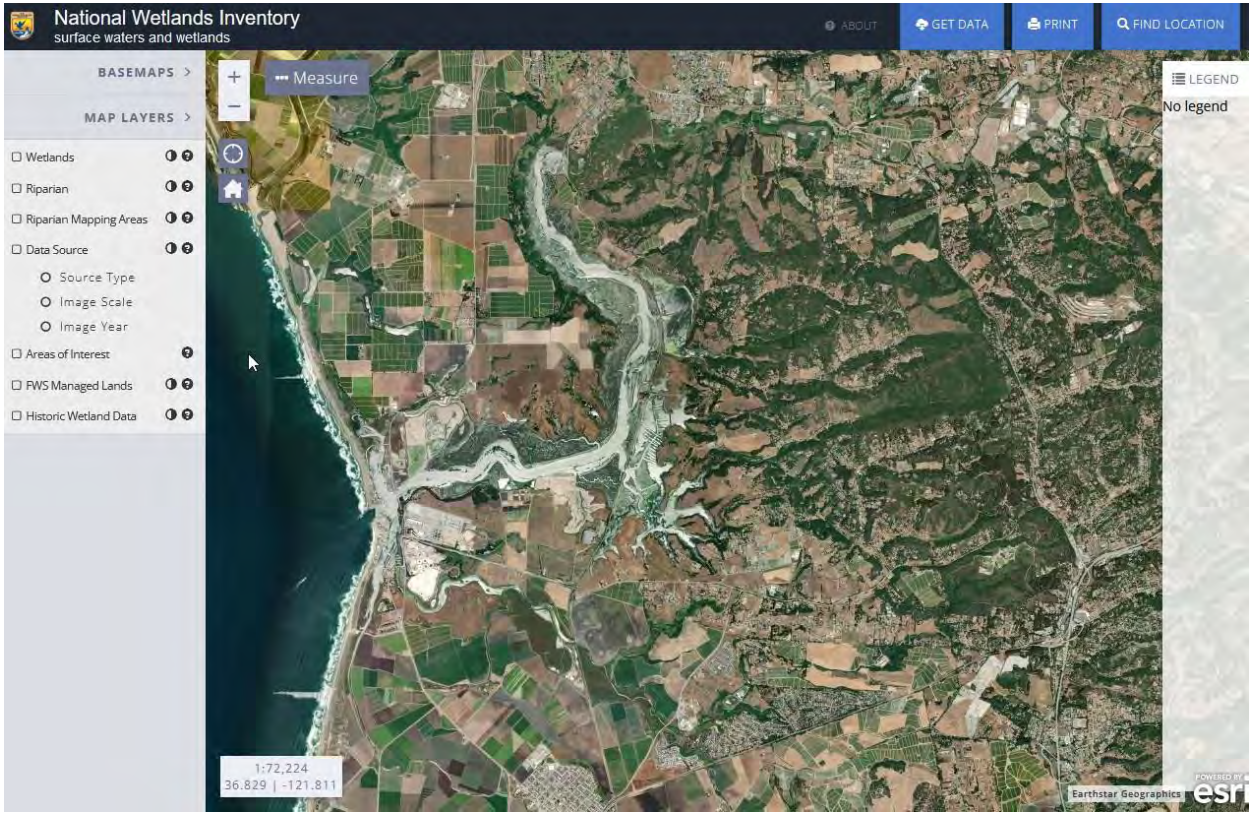


NERRS AS IDEAL PLATFORM

Monitoring short-term variability and long-term change

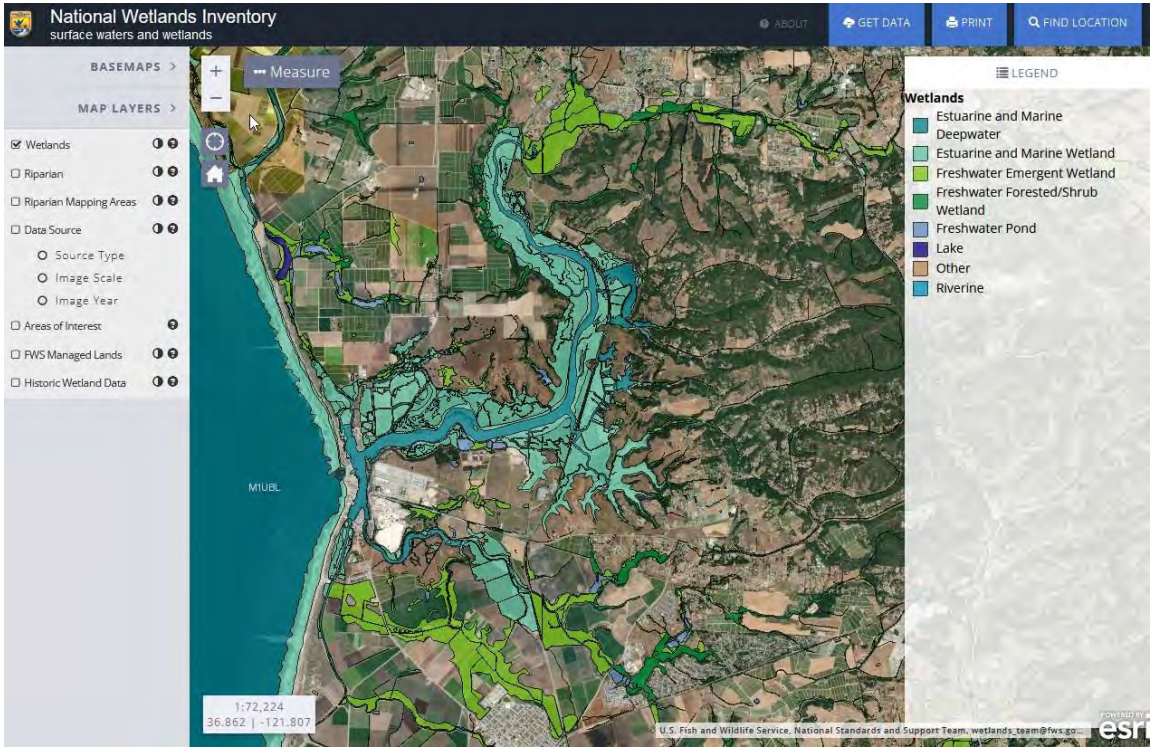
ALTERNATIVES TO AERIAL IMAGERY

Most estuary mapping uses aerial photos



APPROACHES TO COMPLEMENT NWI

National Wetland Inventory maps based primarily on aerial imagery commonly used for US estuary extent



APPROACH

two separate, complementary analyses

ELEVATION-BASED MAPS

- **Large spatial extent**
- **Focus on estuary extent and how it's changed**
- **Useful for mapping past and present estuary**

HISTORICAL MAPS

- **Small spatial extent**
- **Focus on habitat types and how they've changed**
- **Useful for mapping past estuary**

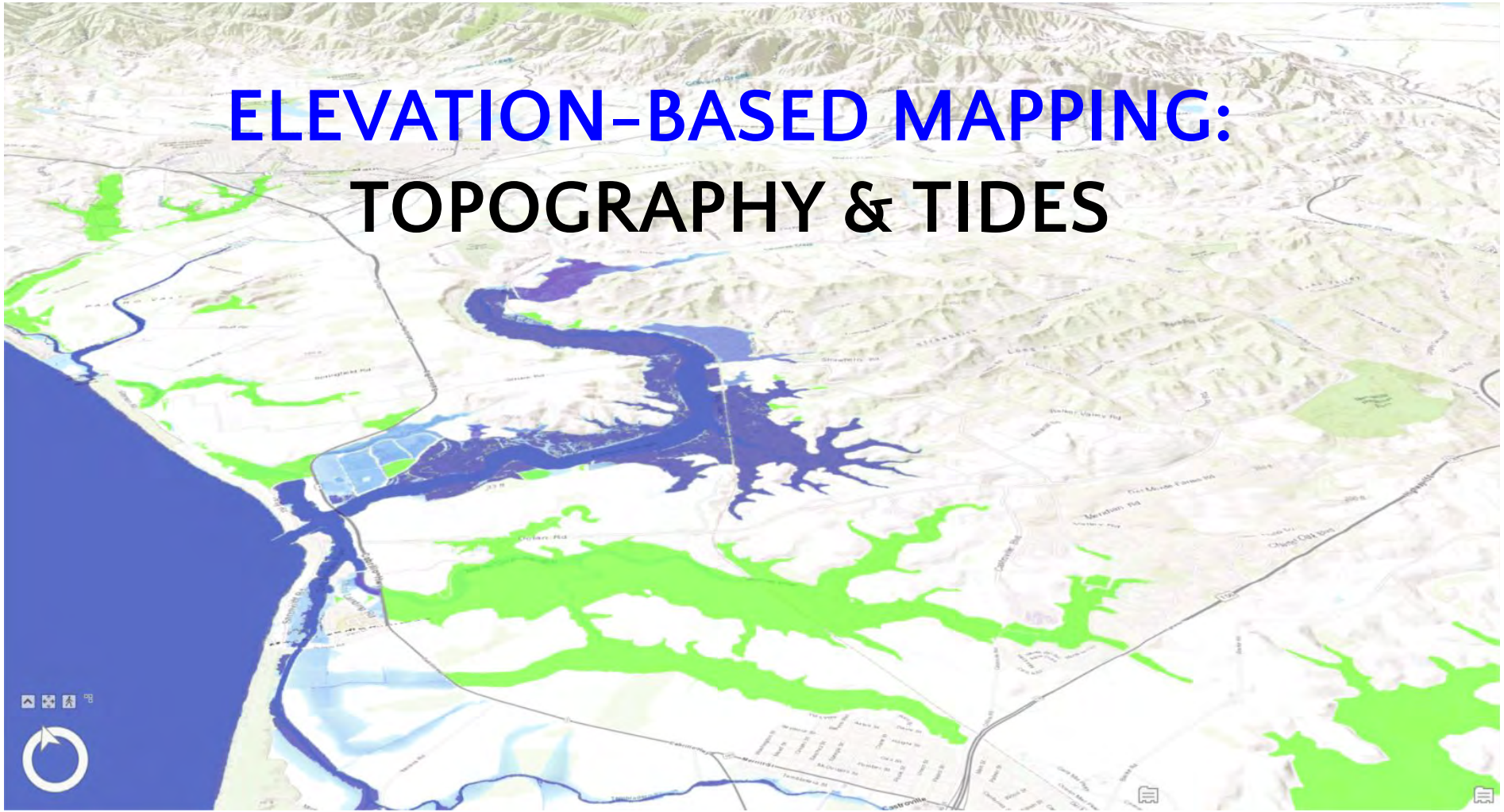
NATIONAL WETLAND INVENTORY

- **Often used for mapping present estuary**

Why map estuaries?

How? Elevation-based mapping
Historical mapping

What did we learn?

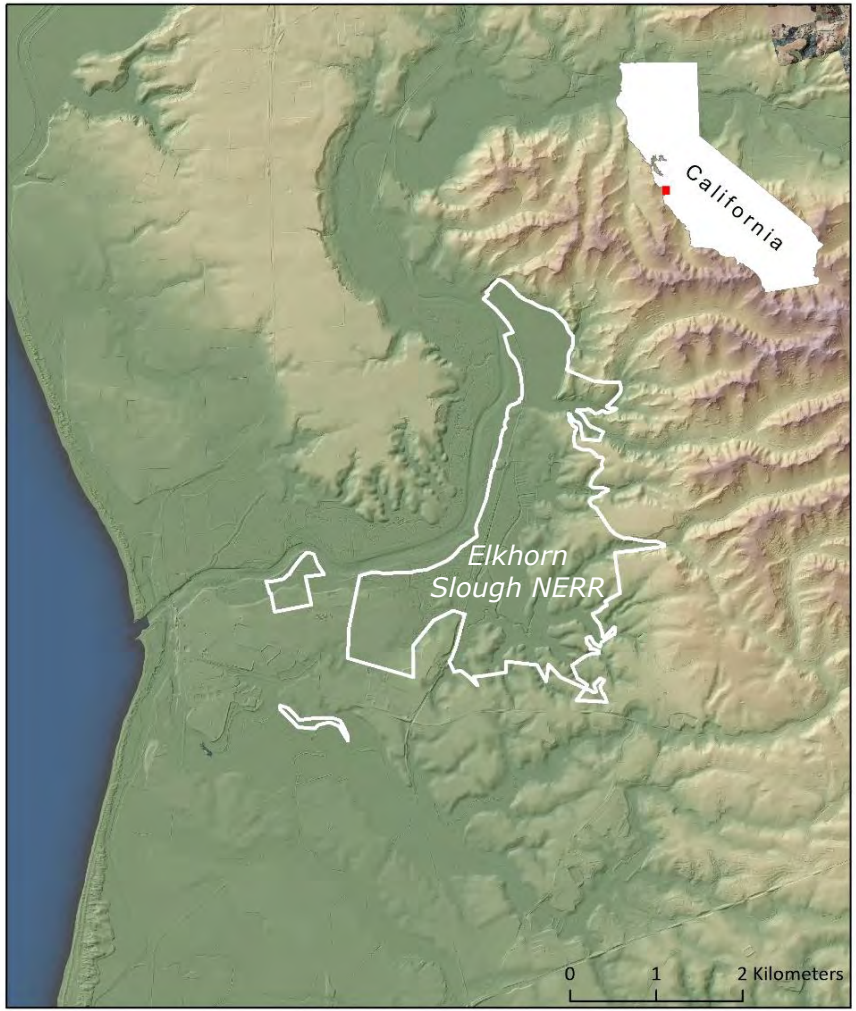

ELEVATION-BASED MAPPING:
TOPOGRAPHY & TIDES

DATA SOURCES

Topography

- *Digital Elevation Models*

https://coast.noaa.gov/slrdata/



DATA SOURCES

Topography

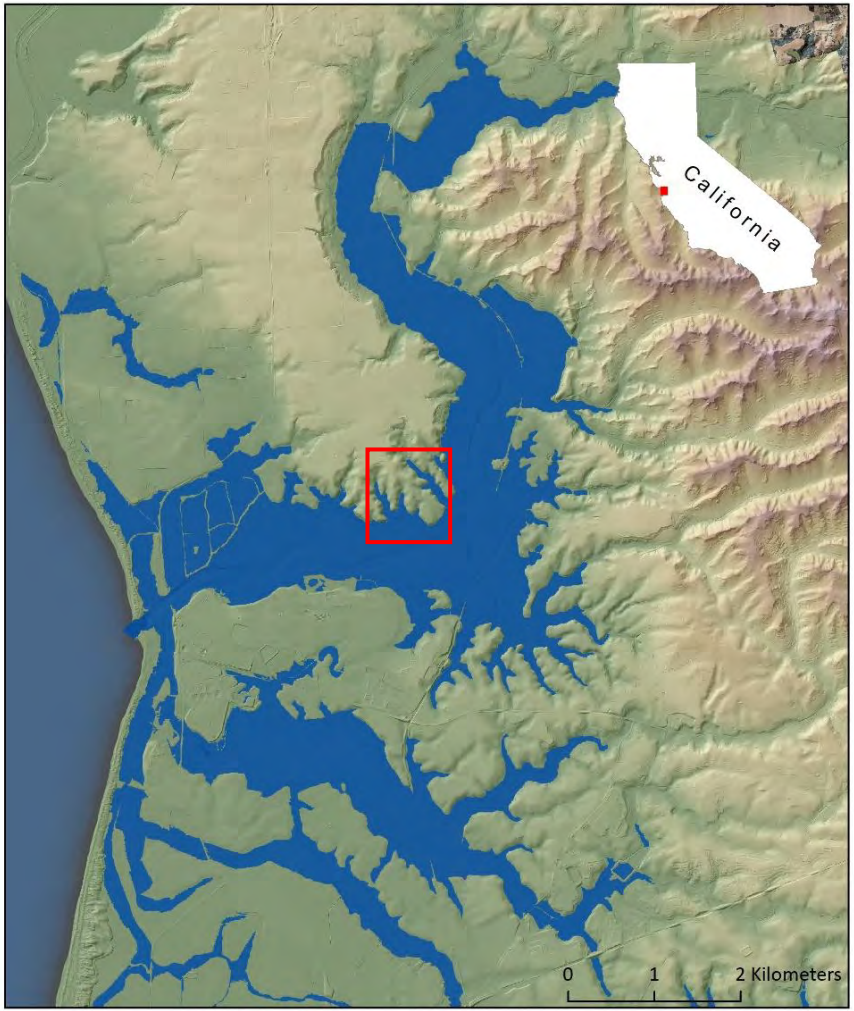
- *Digital Elevation Models*
- *Water Level Data*
  - *NOAA & Army Corps of Engineers study*

https://coast.noaa.gov/slrdata/

DATA SOURCES

Topography

Estuary Extent



DATA SOURCES

Topography

Estuary Extent

DATA SOURCES

Topography

Estuary Extent

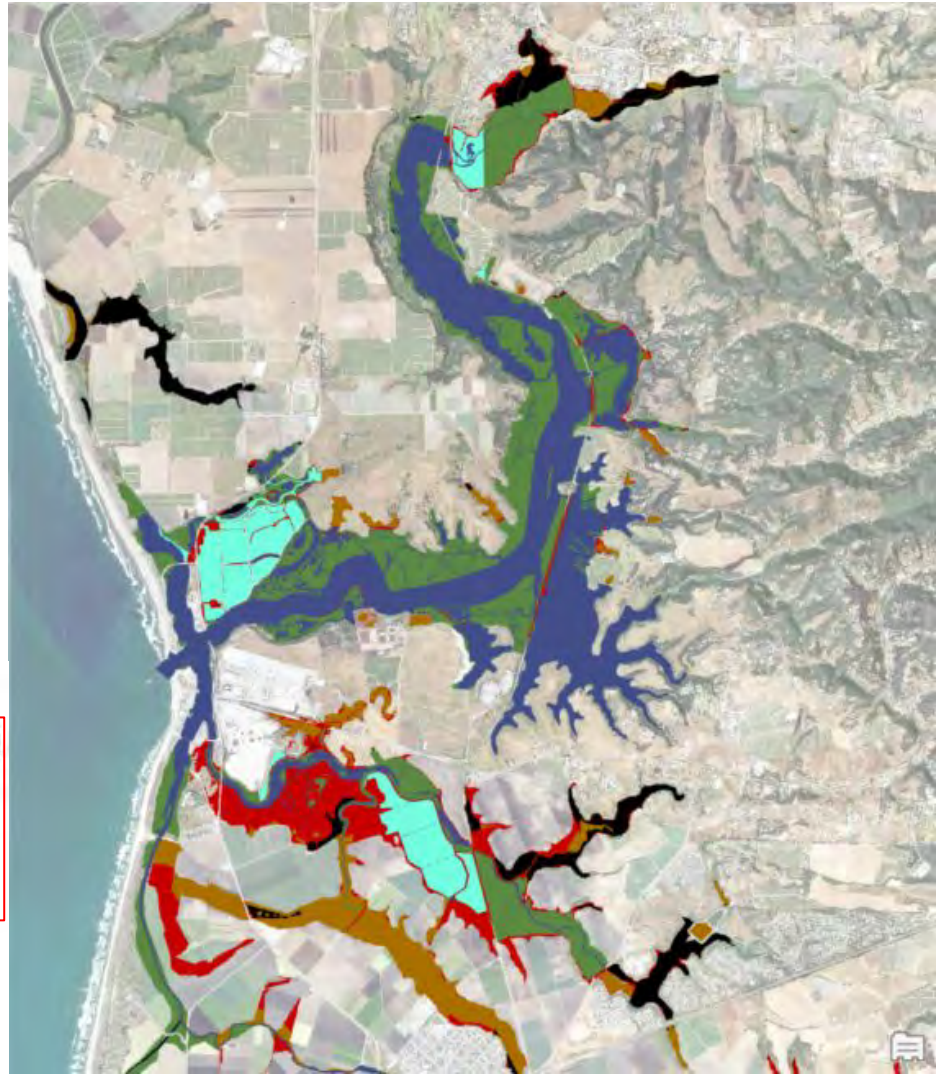
DATA SOURCES

Topography

Estuary Extent

COMPARISON TO NWI

Grouped NWI Habitats



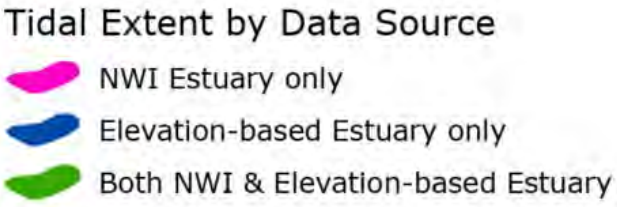
Tidal

Nontidal

COMPARISON TO NWI

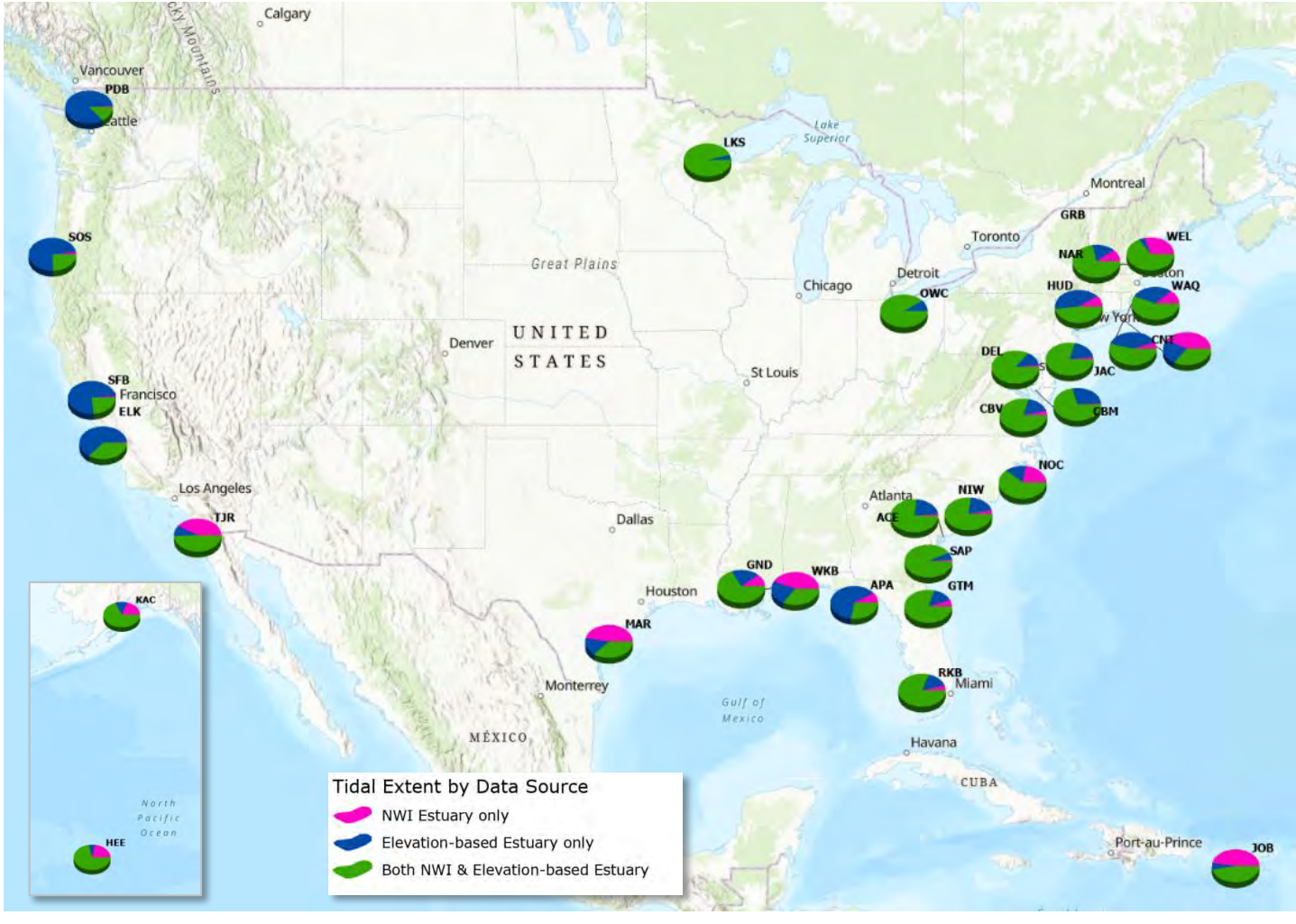
Areas not in NWI can represent loss

(or they may represent tidal wetlands missing from NWI)

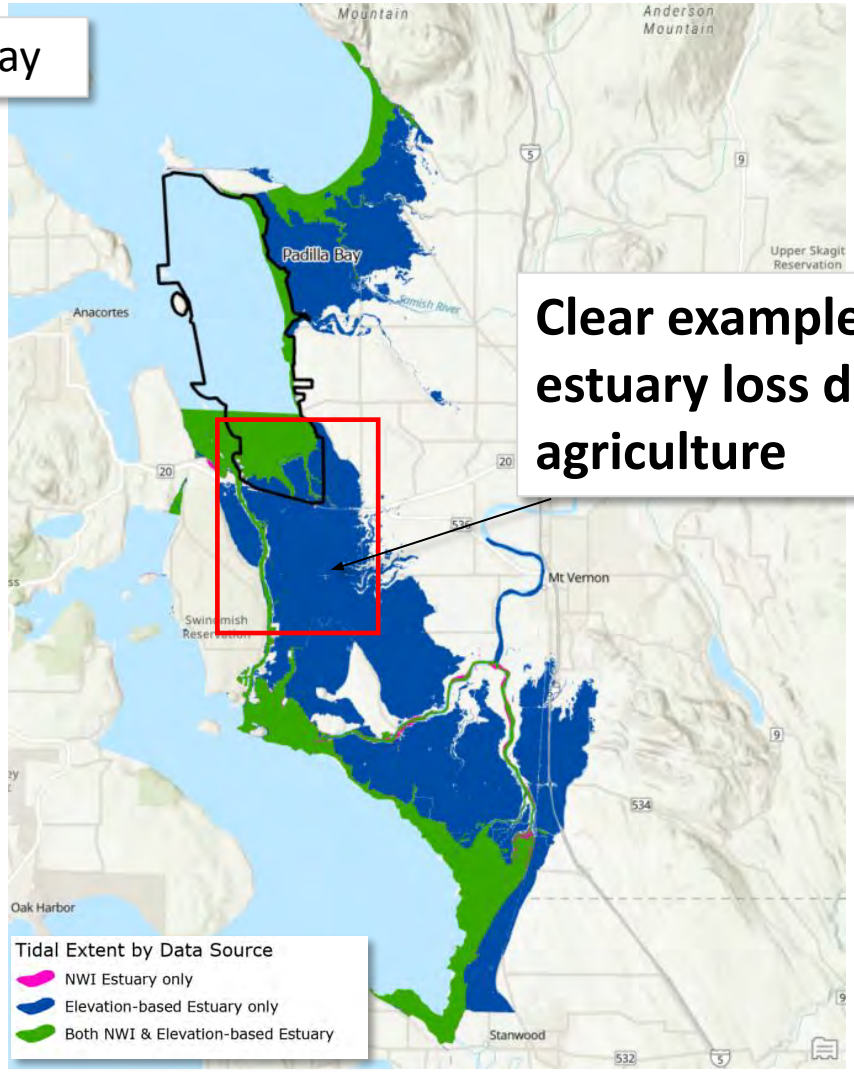


COMPARISON TO NWI

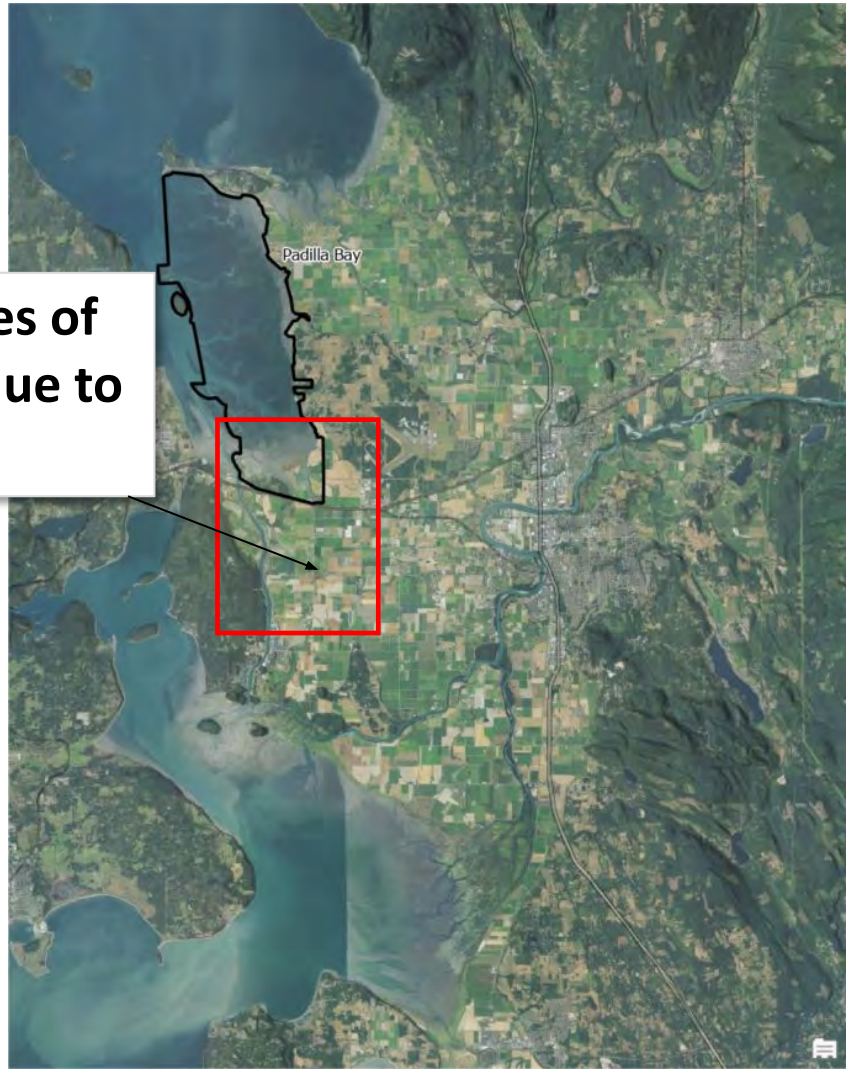
Regional Patterns



Padilla Bay

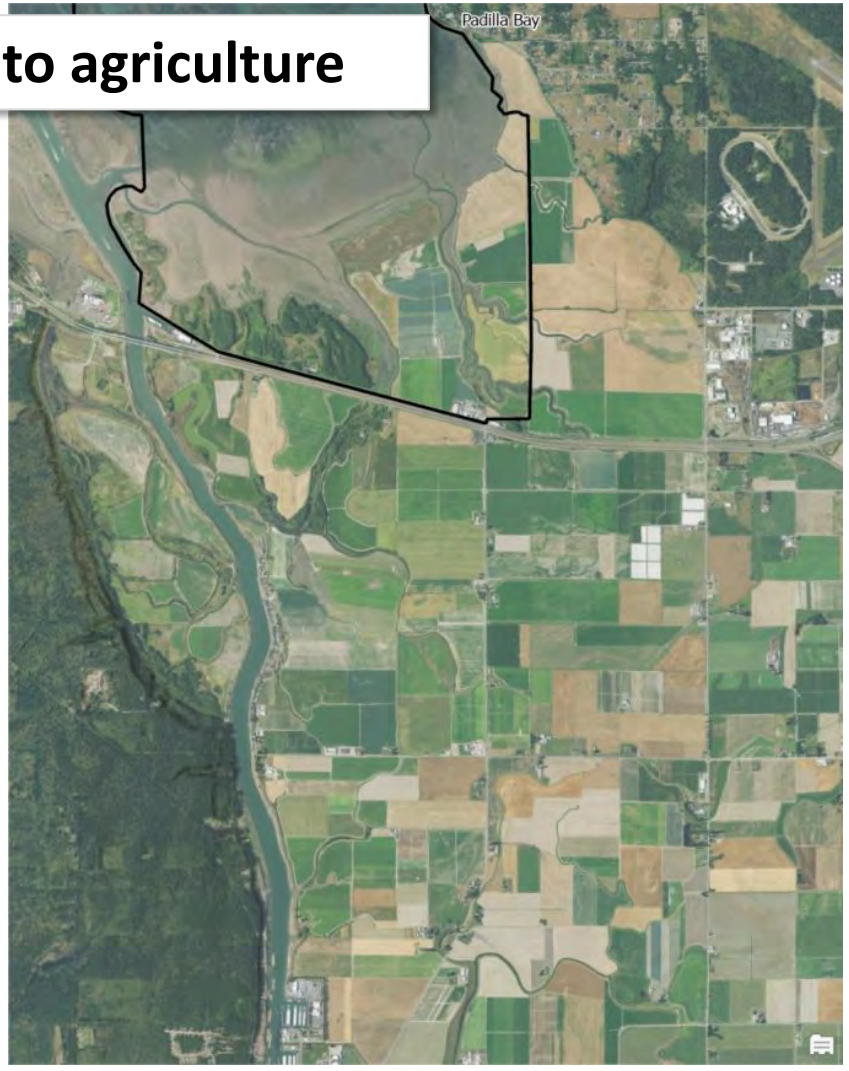


Clear examples of estuary loss due to agriculture



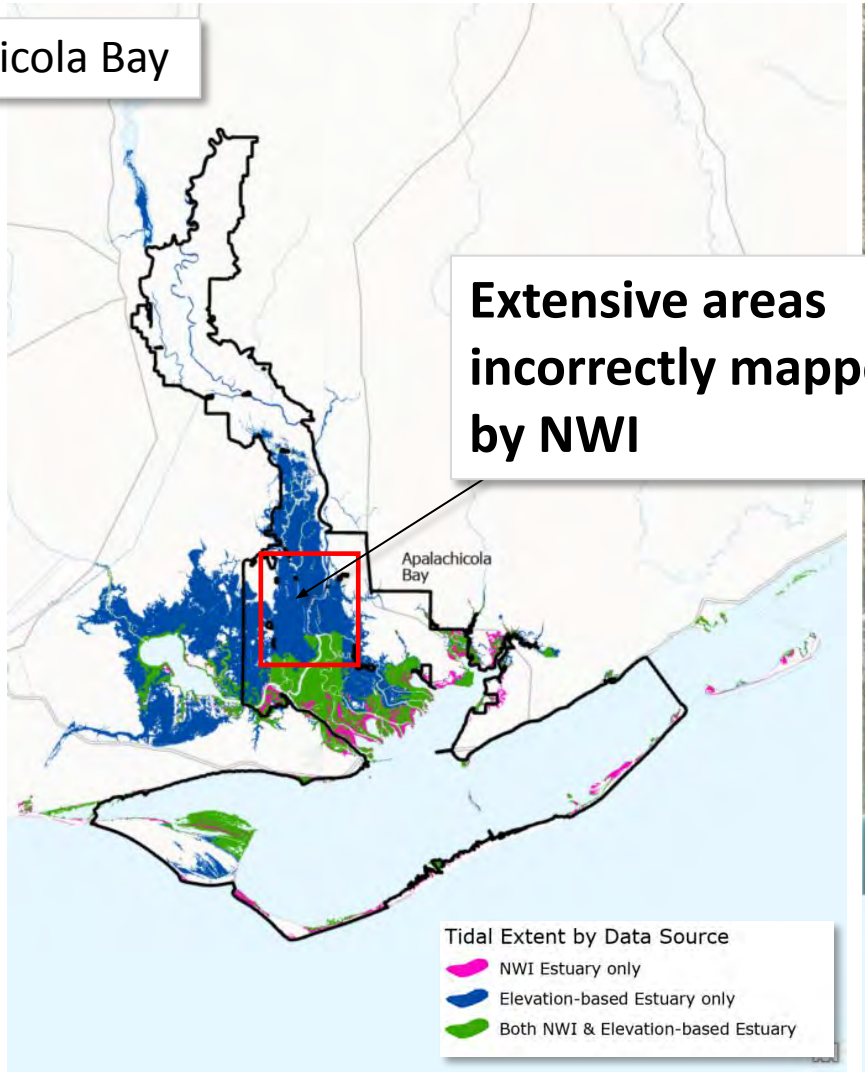
Padilla Bay

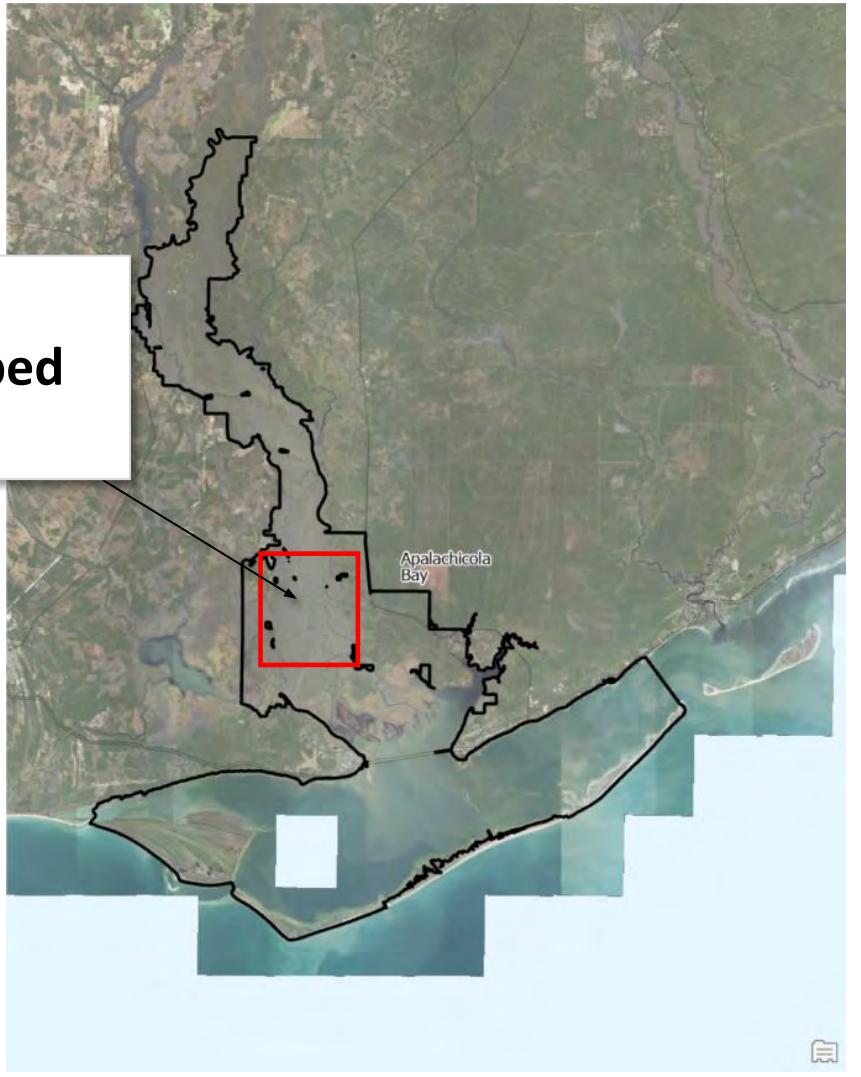
Estuary loss due to agriculture



Apalachicola Bay

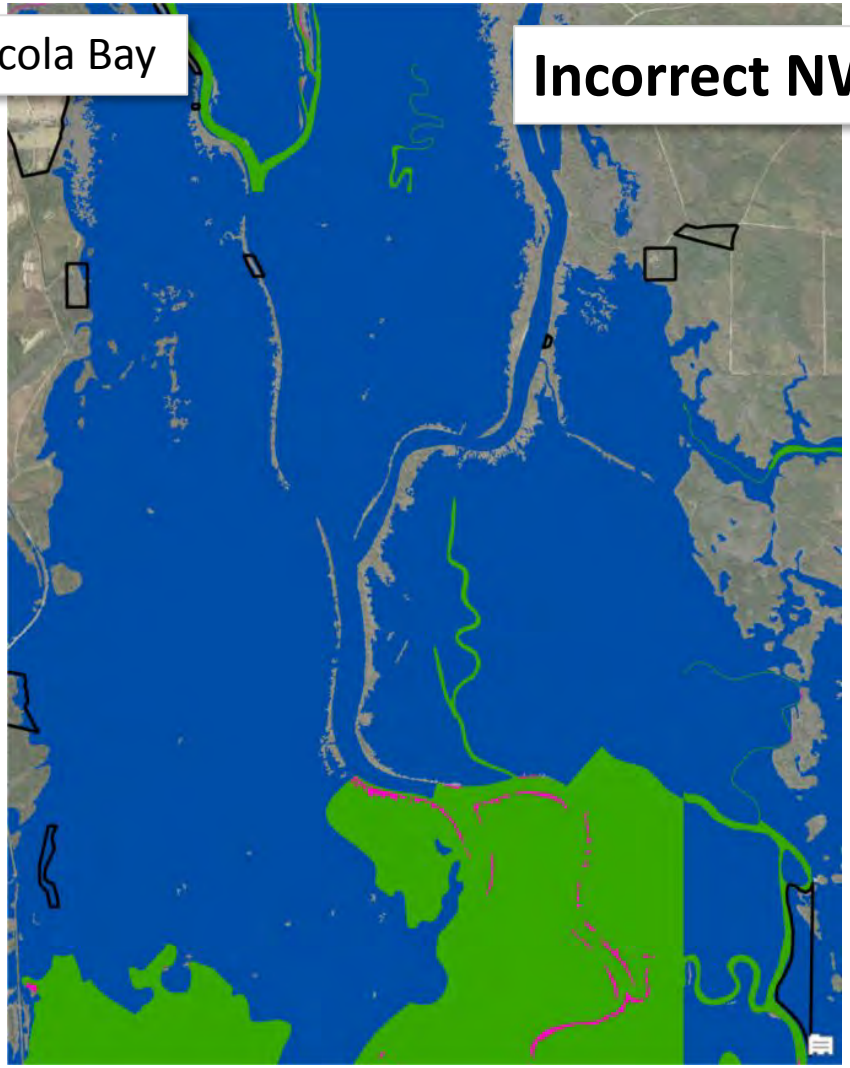
Extensive areas incorrectly mapped by NWI

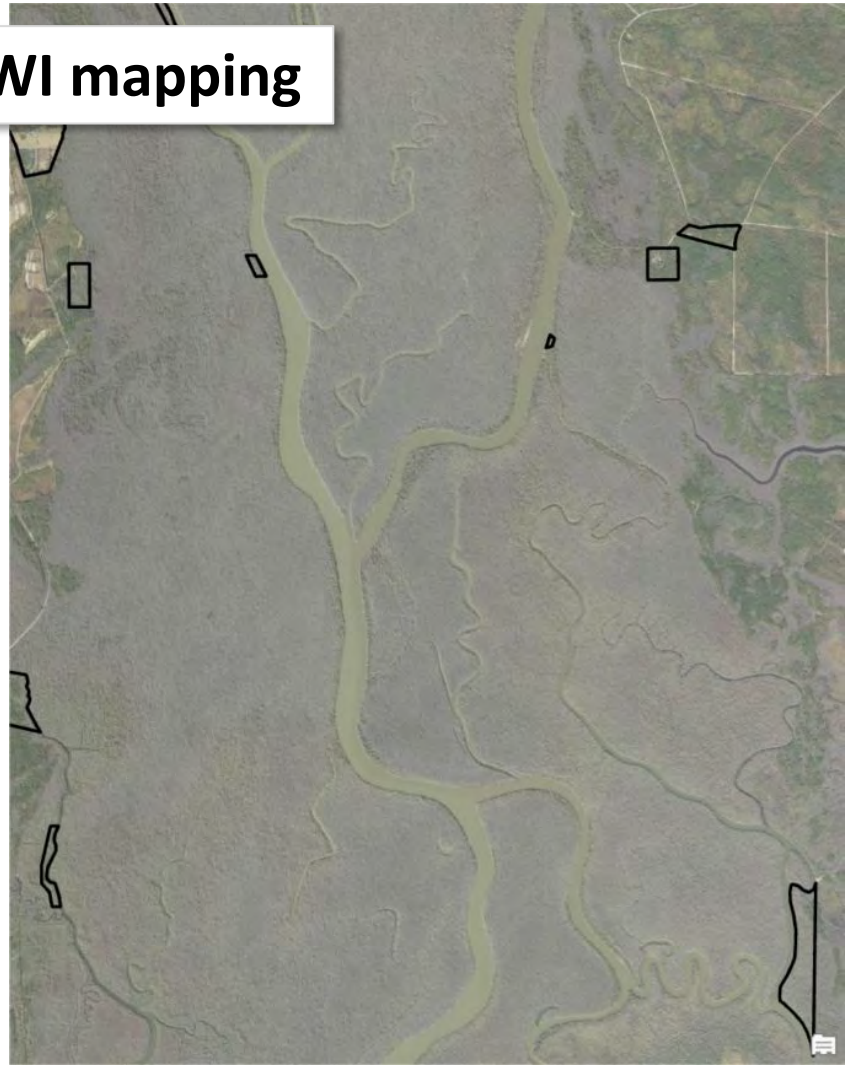




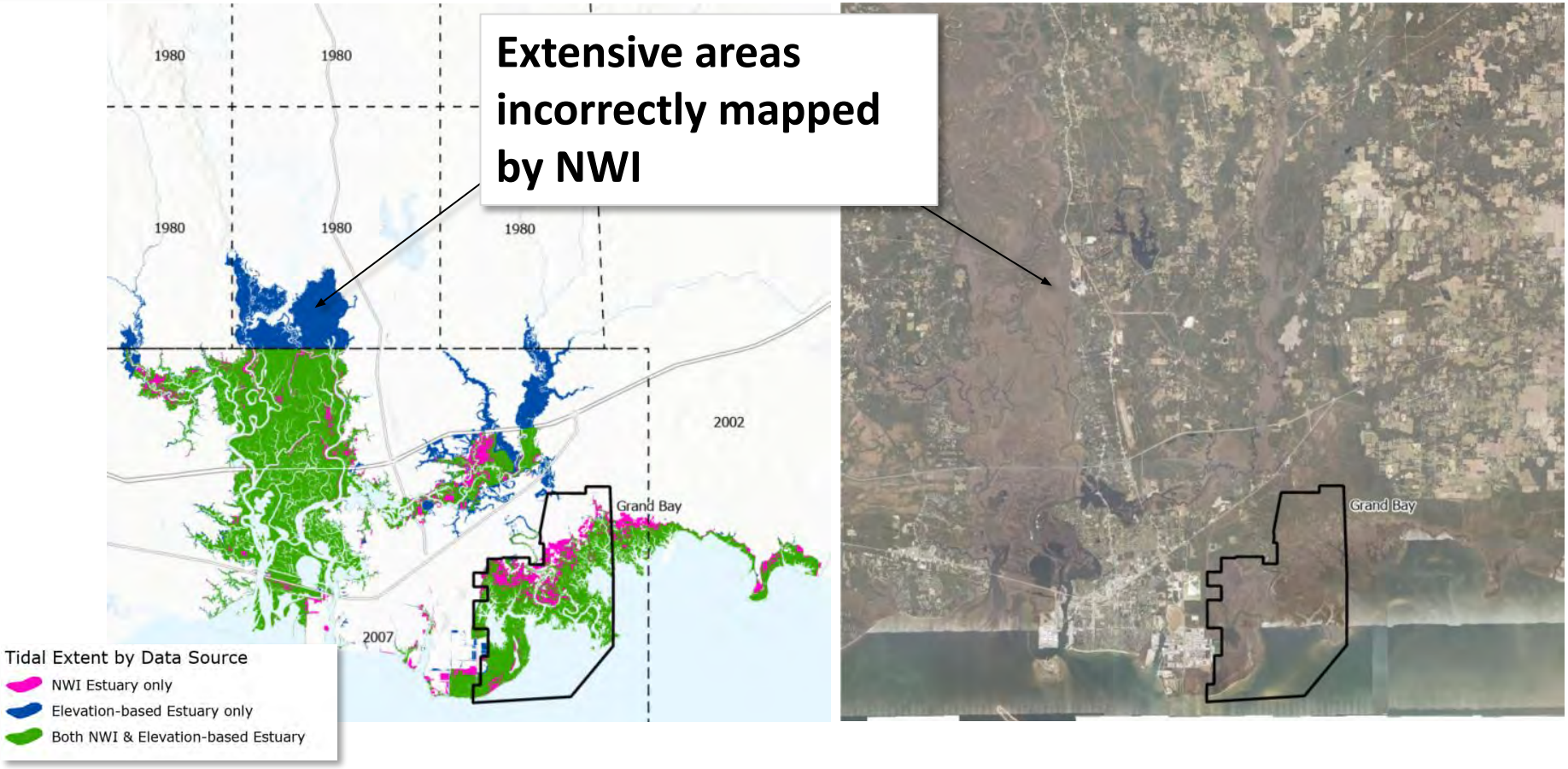
Apalachicola Bay

Incorrect NWI mapping

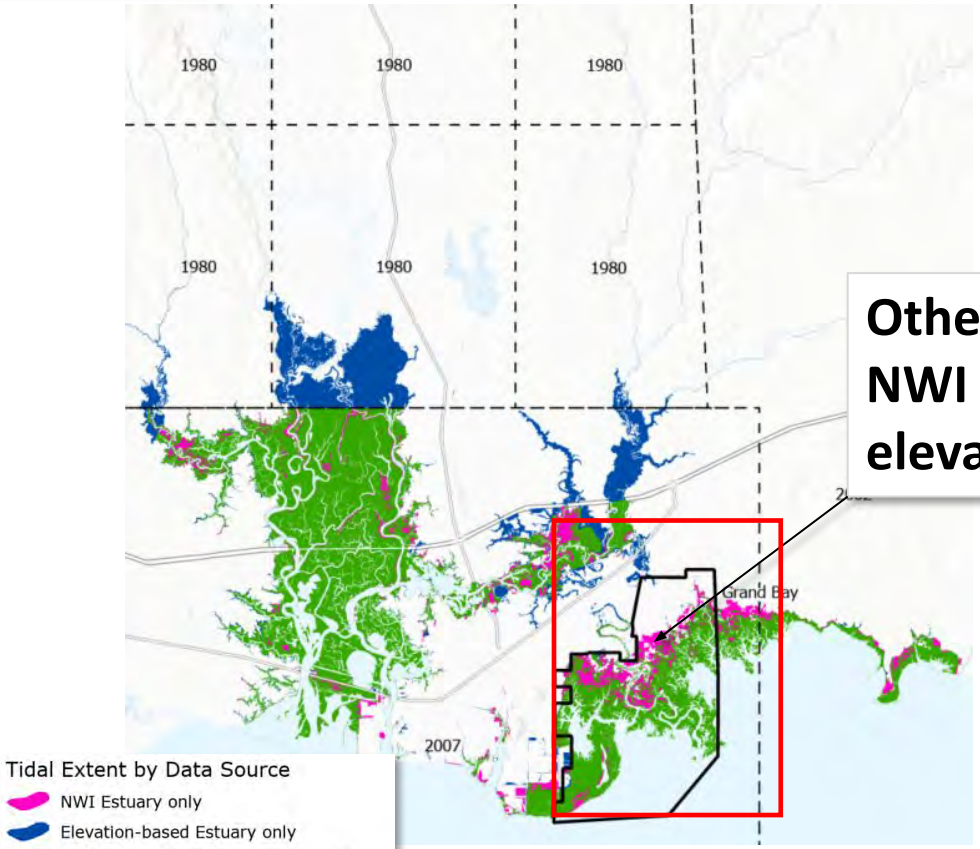




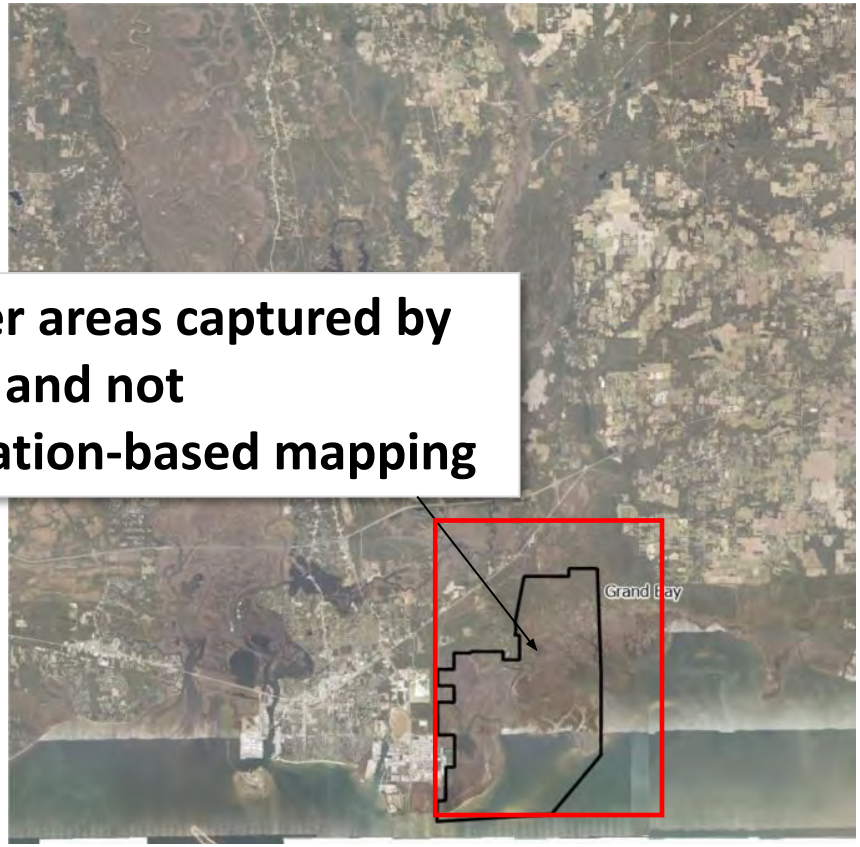
Grand Bay


Extensive areas incorrectly mapped by NWI
1980
1980
1980
1980
1980
2002
2007
Grand Bay
Grand Bay
Tidal Extent by Data Source
NWI Estuary only
Elevation-based Estuary only
Both NWI & Elevation-based Estuary

Grand Bay

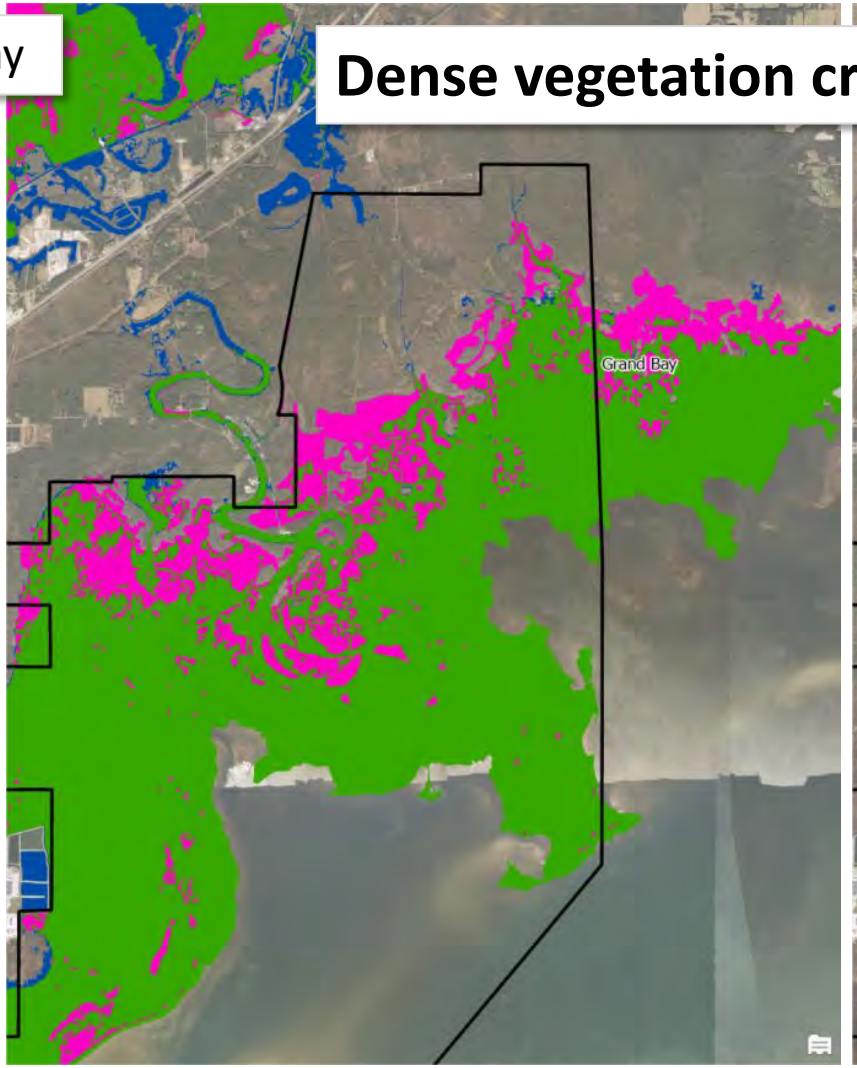


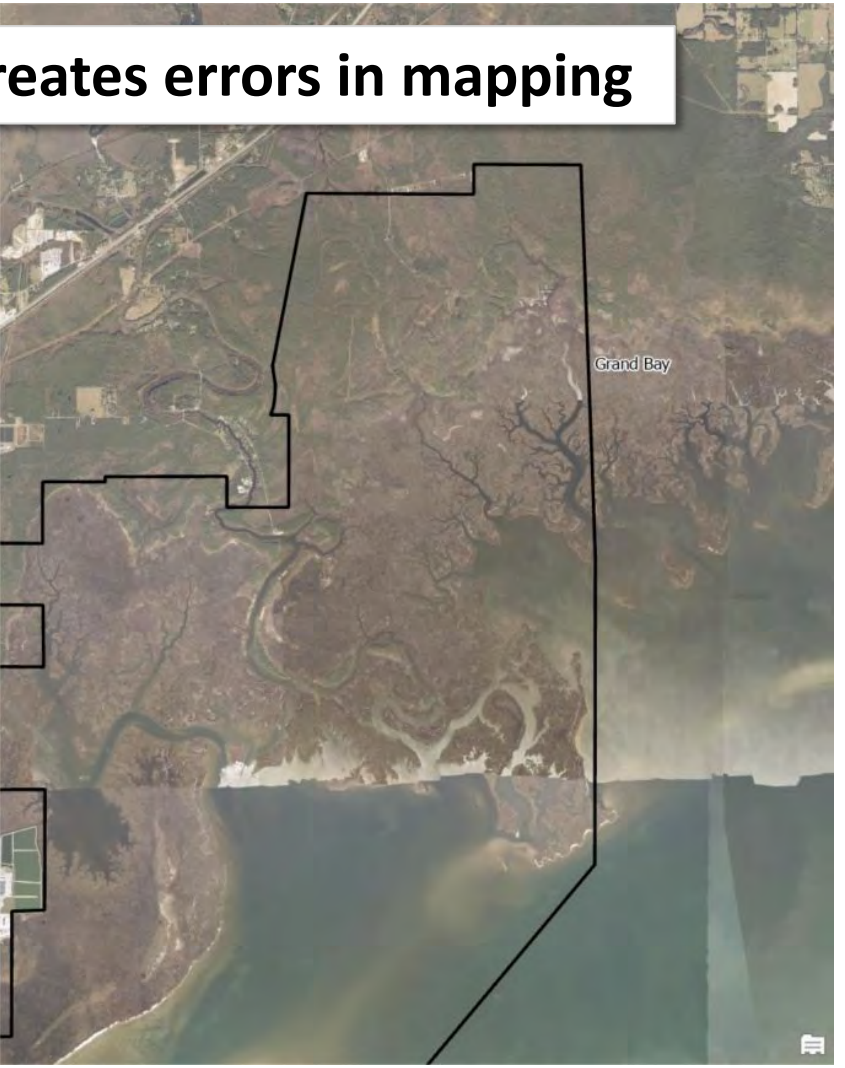
Other areas captured by NWI and not elevation-based mapping



Grand Bay

Dense vegetation creates errors in mapping





ELEVATION-BASED MAPPING:
Summary

- Effective for identifying the full extent of tidal wetlands
- Both NWI and Elevation-based mapping can contain errors: together they provide more accurate map of estuary

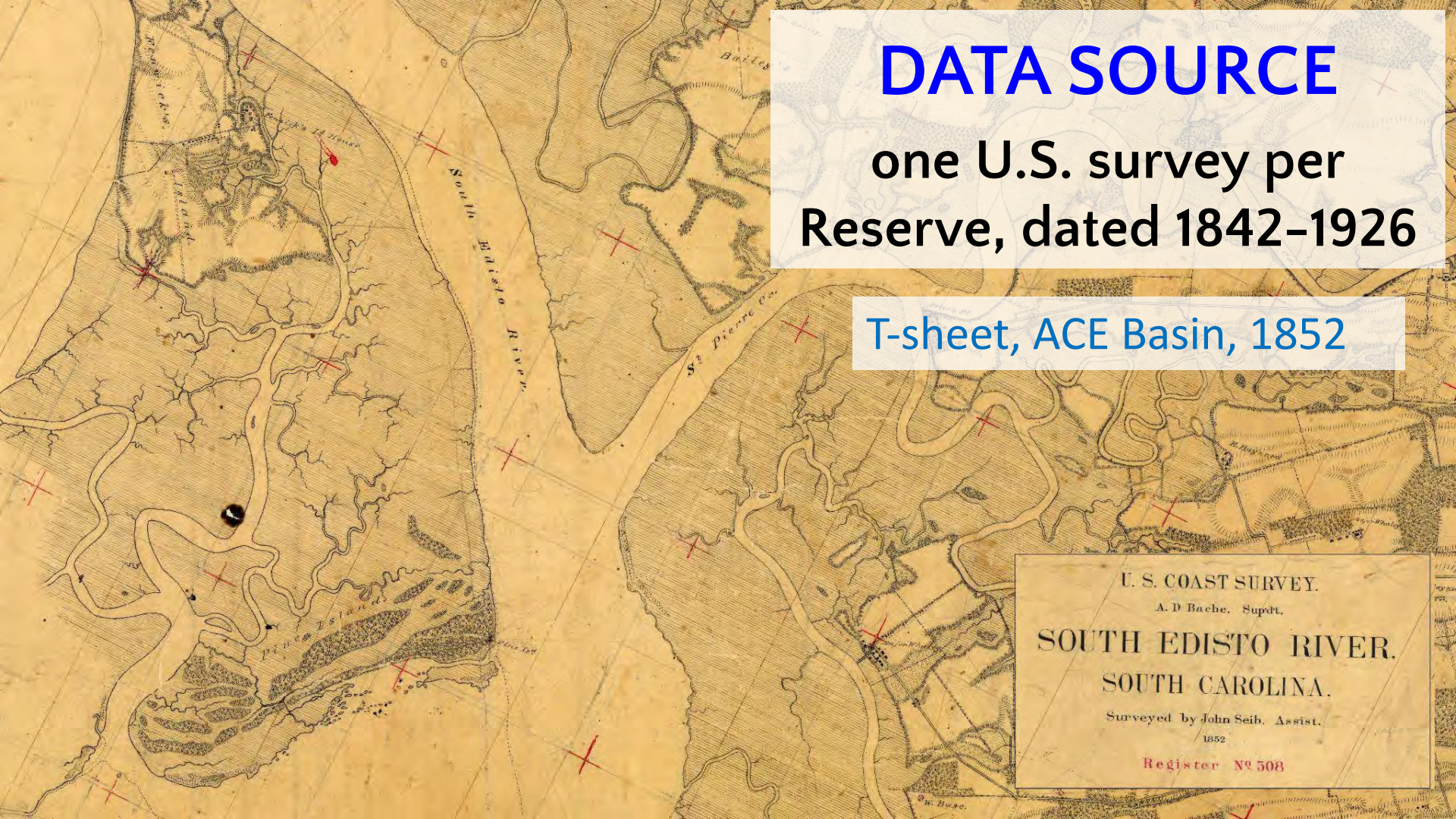
Why map estuaries?

How? Elevation-based mapping
Historical mapping

What did we learn?

HISTORICAL MAPPING

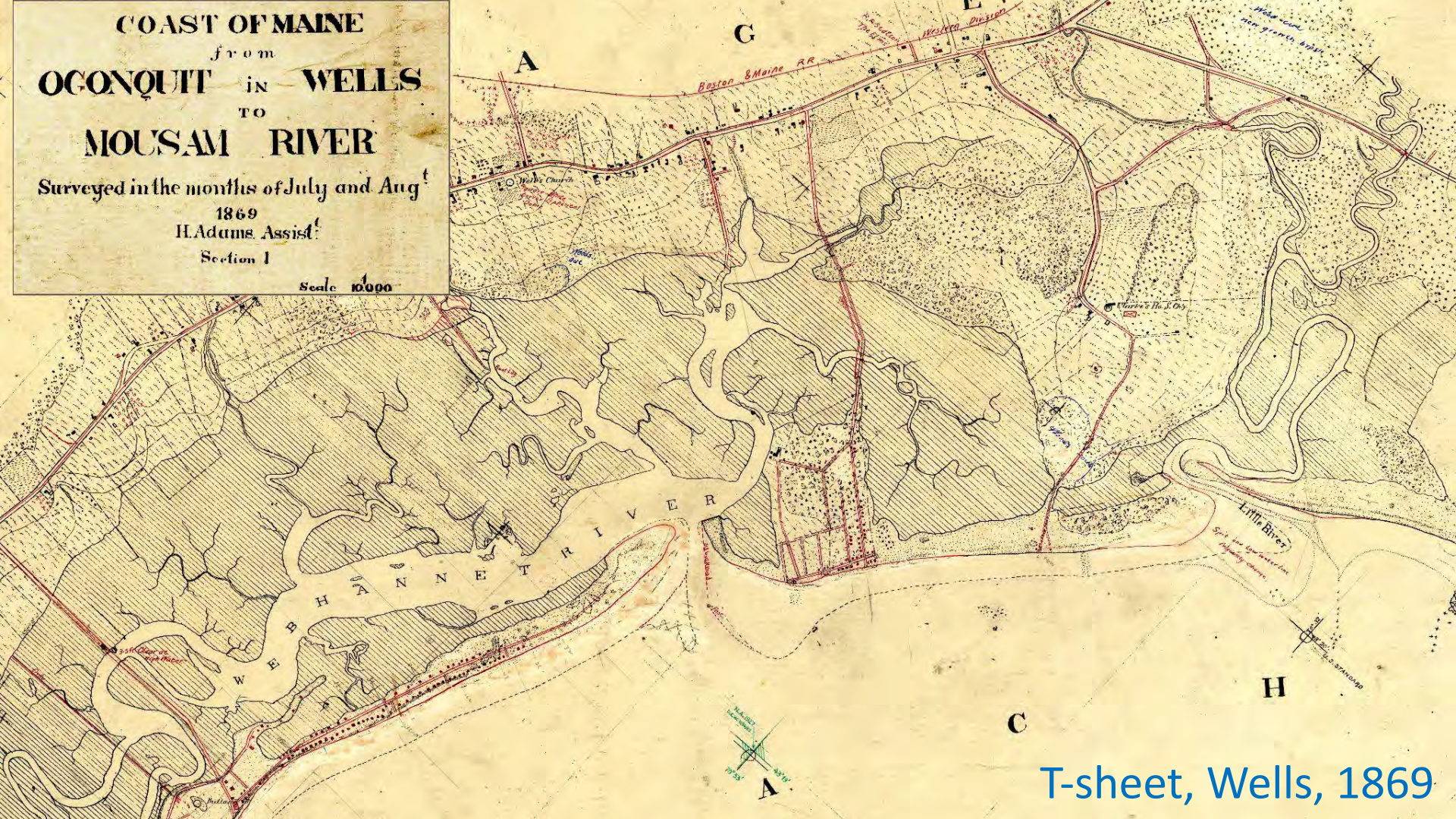
U.S. Coast Survey
J. R. Hassler Superintendent
Bombay Hook Island to
Mispillion Creek
Delaware
Surveyed by J. H. Gerdes
1842
Scale 1-20,000



DATA SOURCE

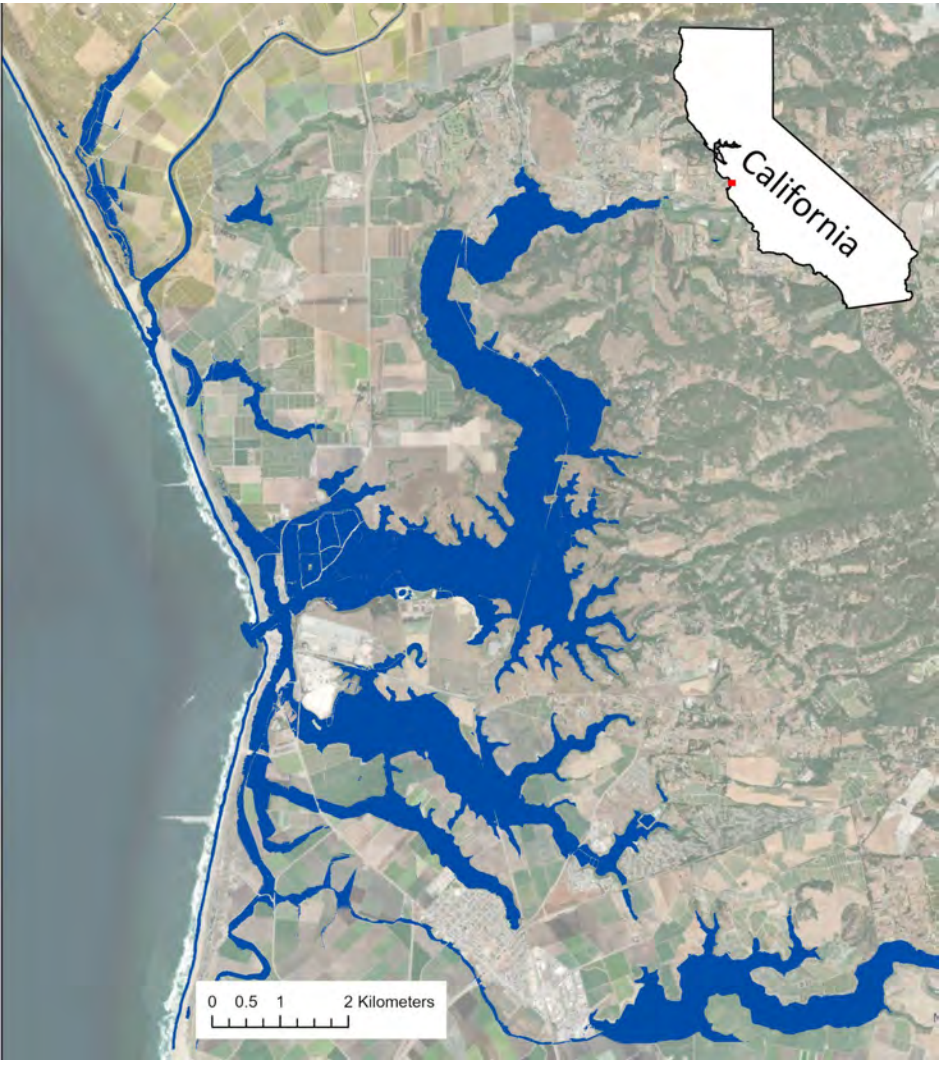
one U.S. survey per Reserve, dated 1842–1926

T-sheet, ACE Basin, 1852



T-sheet, Wells, 1869

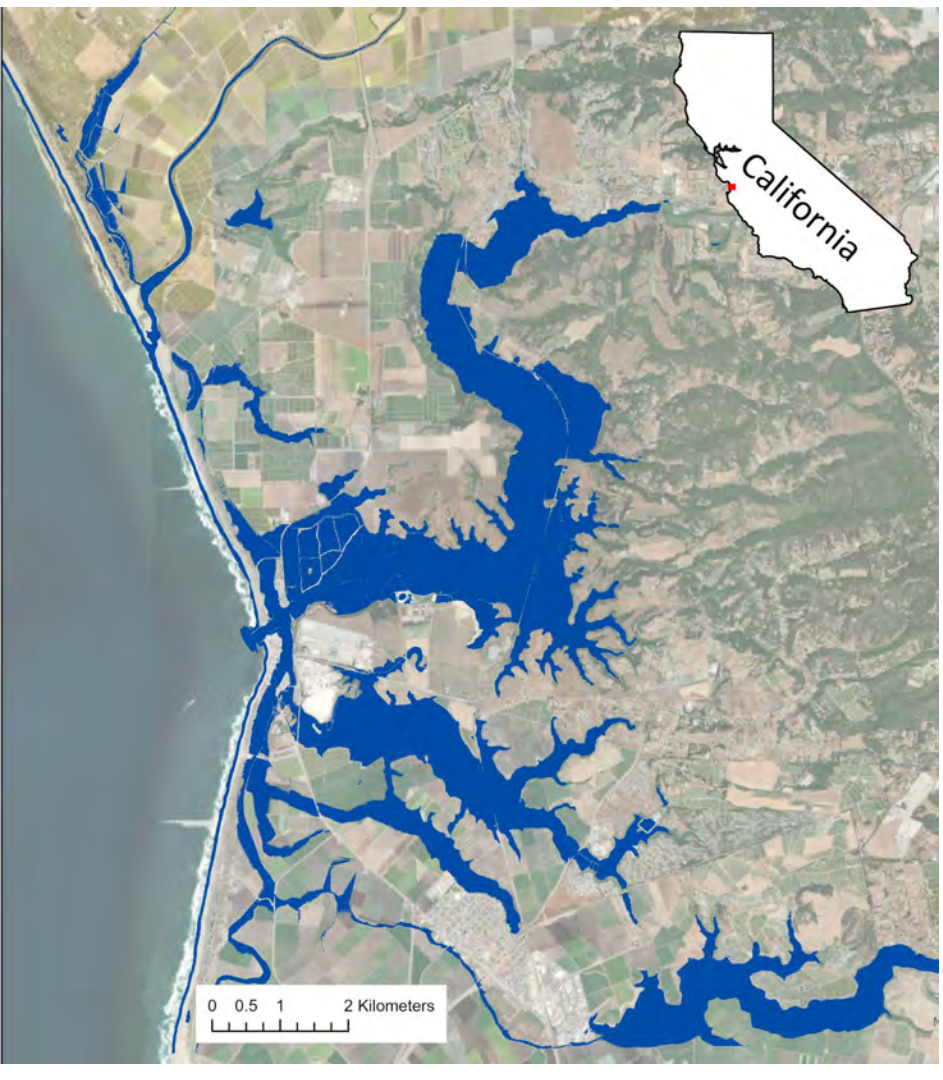
Lake survey,
Lake Superior, 1861

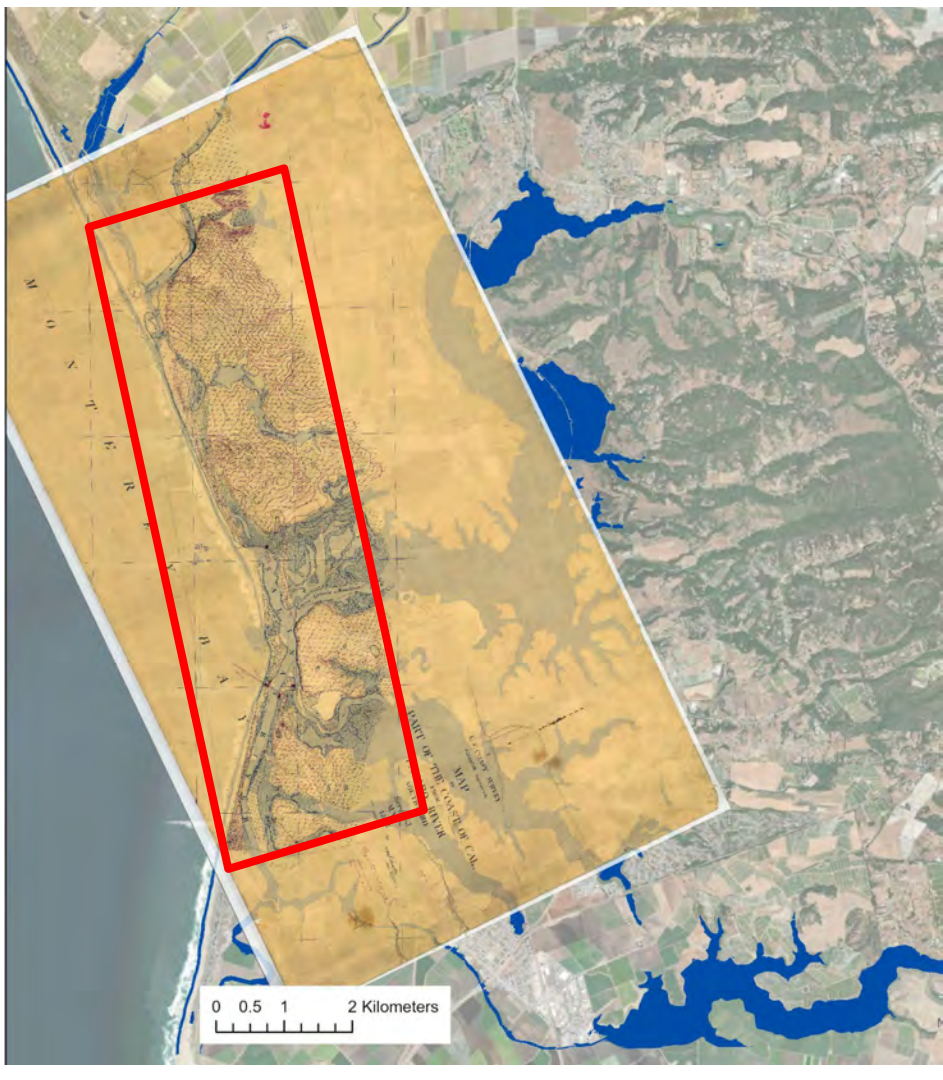


SCALE OF MAPPING

boundaries of one map –

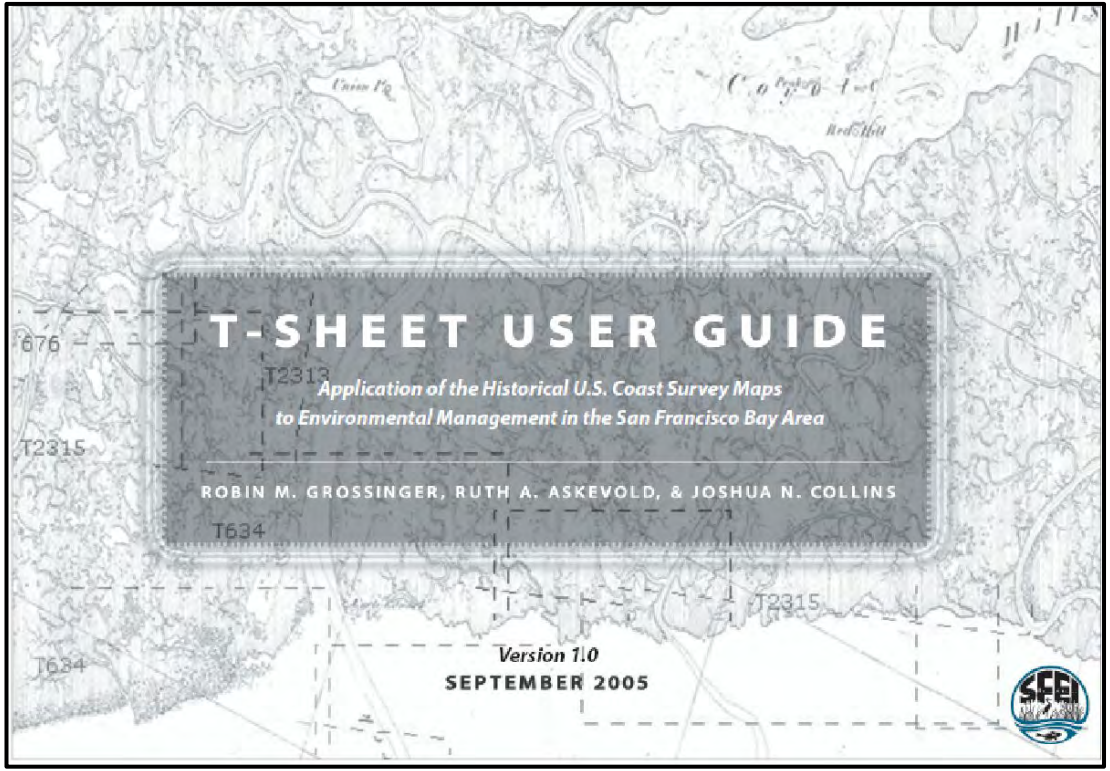
a “sample” of estuary

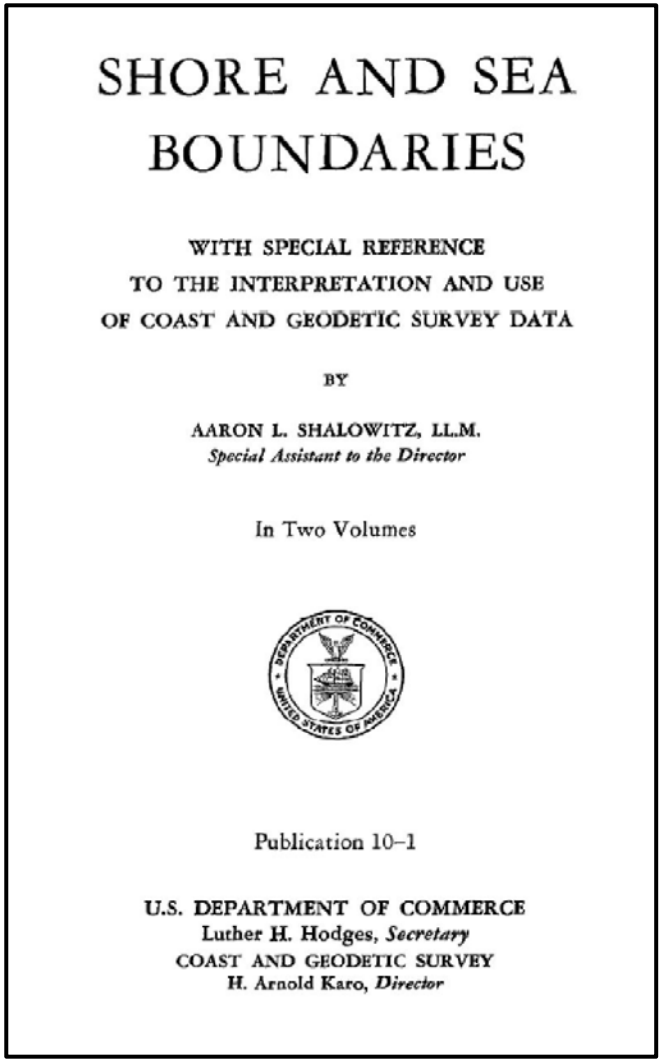

California
0 0.5 1 2 Kilometers


0 0.5 1 2 Kilometers

RECONSTRUCTING PAST

Mapping estuarine habitats





SHORE AND SEA BOUNDARIES

WITH SPECIAL REFERENCE
TO THE INTERPRETATION AND USE
OF COAST AND GEODETIC SURVEY DATA

BY

AARON L. SHALOWITZ, LL.M.
Special Assistant to the Director

In Two Volumes

Publication 10–1

U.S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*
COAST AND GEODETIC SURVEY
H. Arnold Karo, *Director*

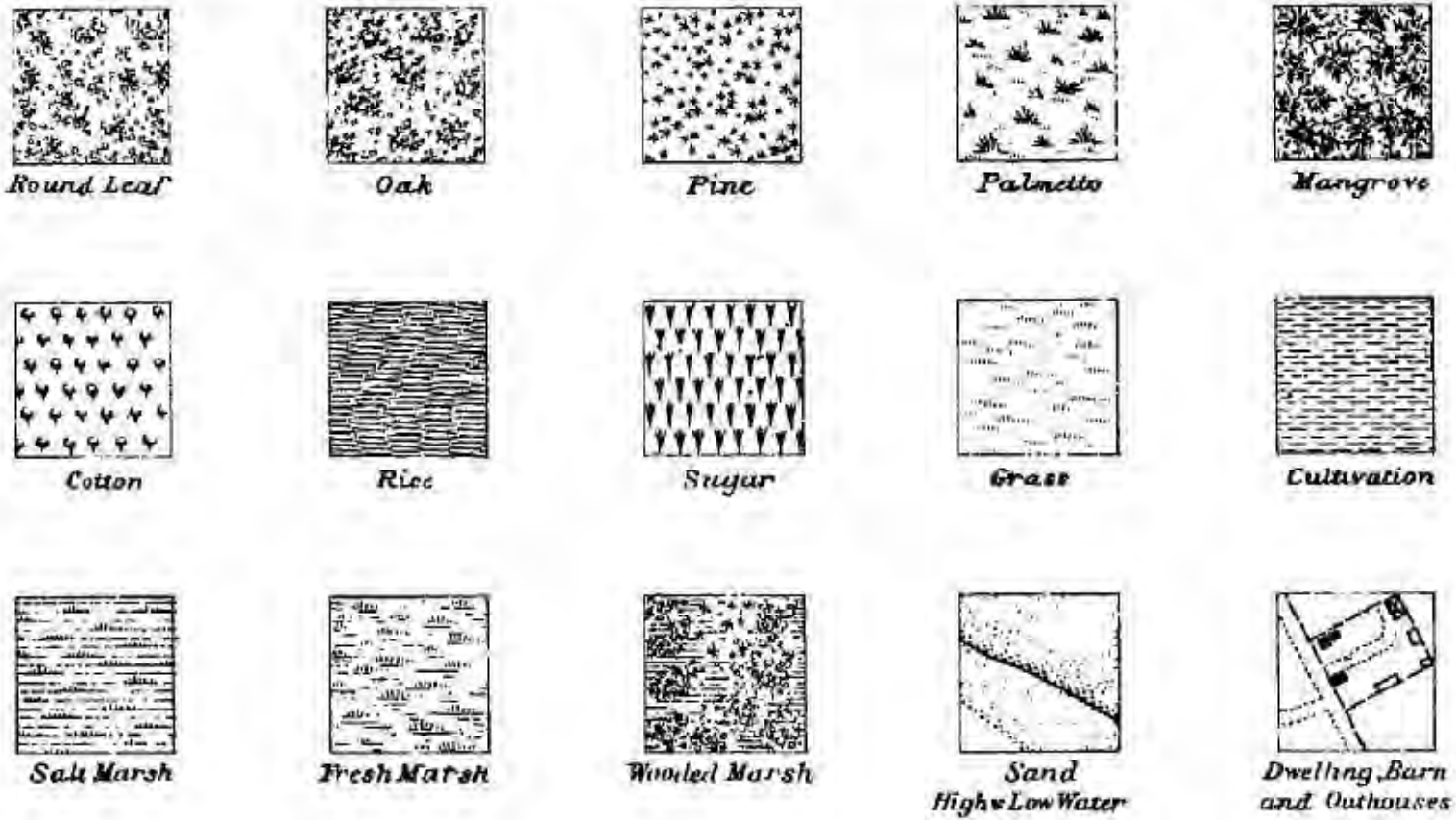
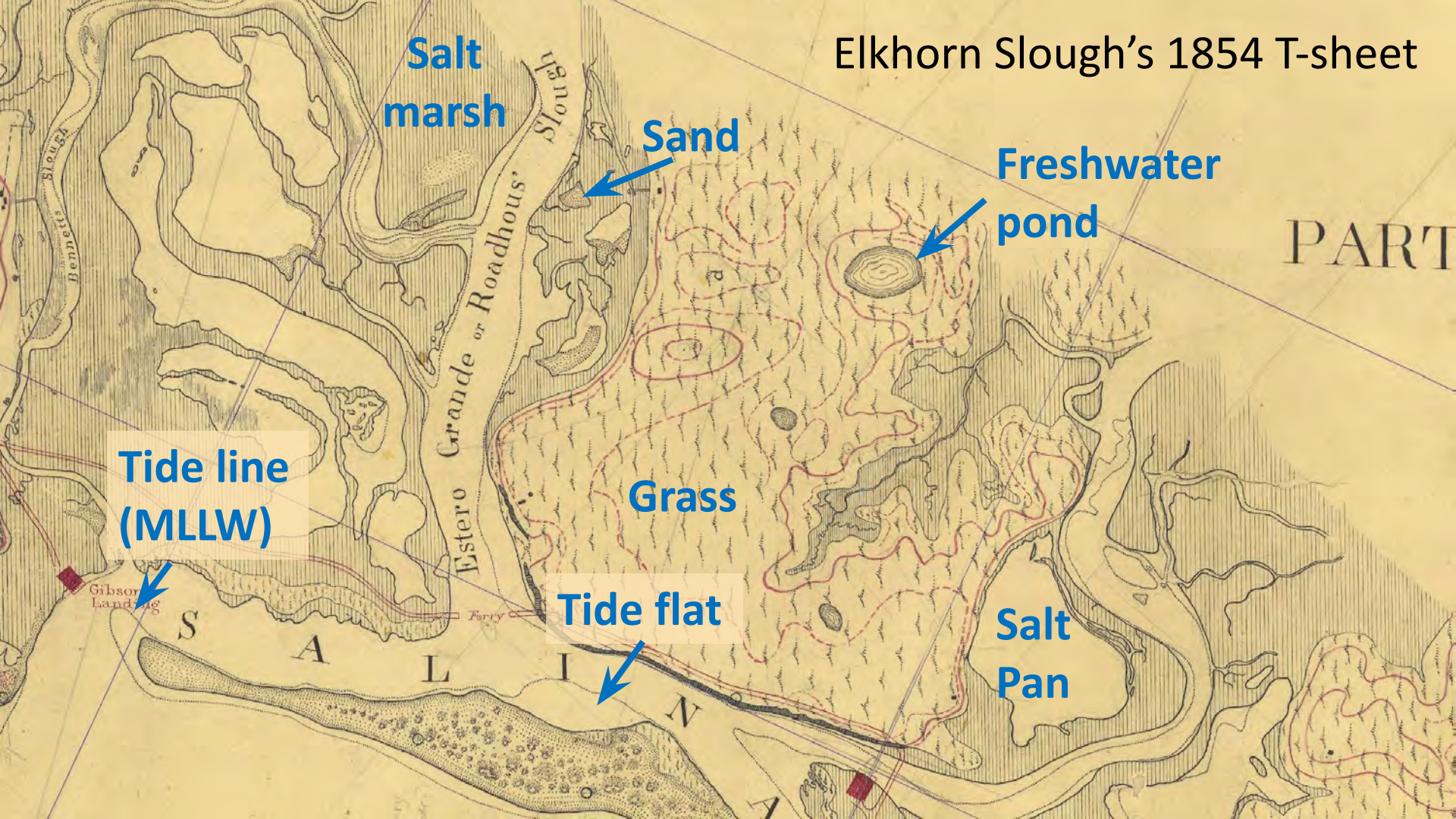
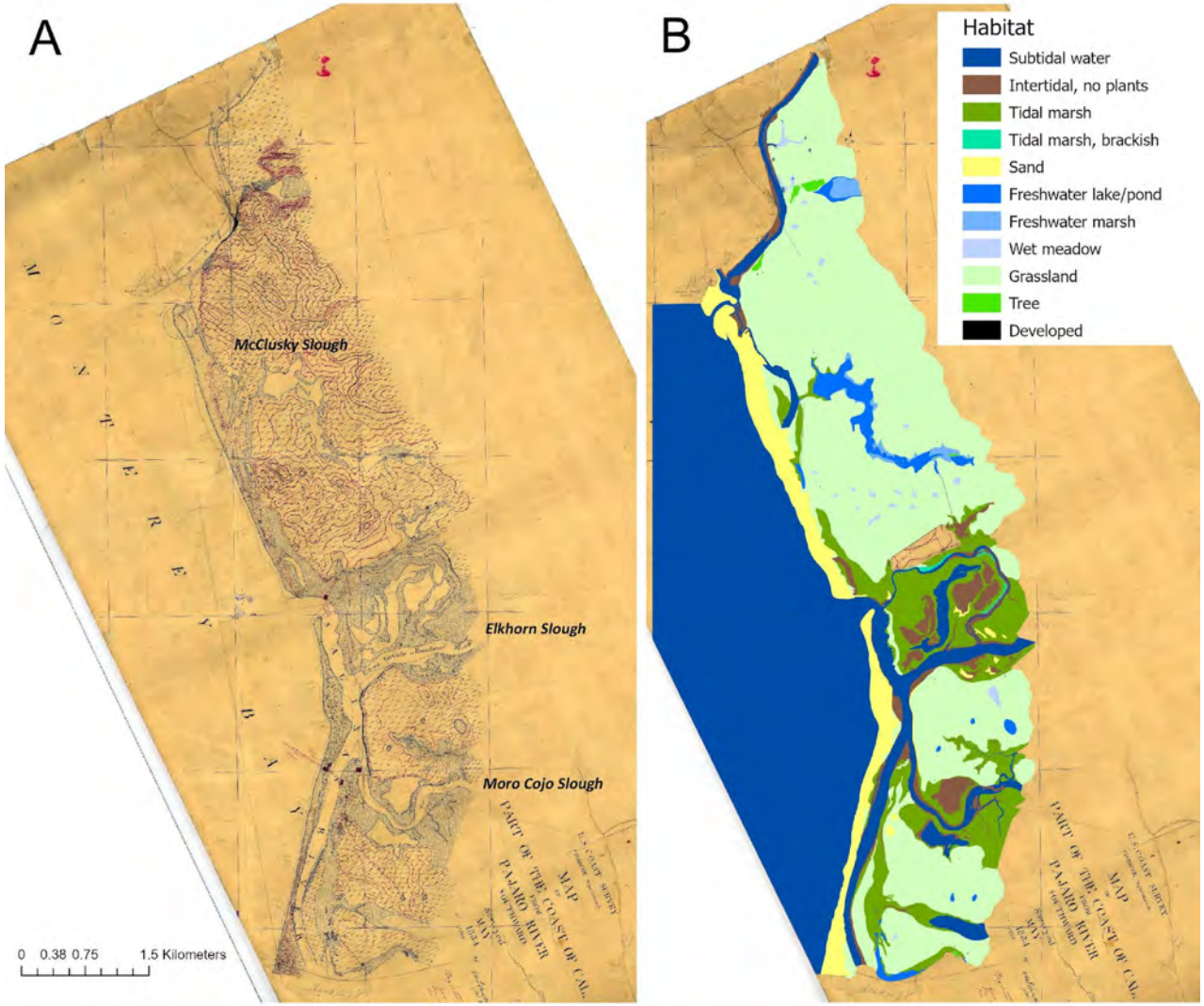
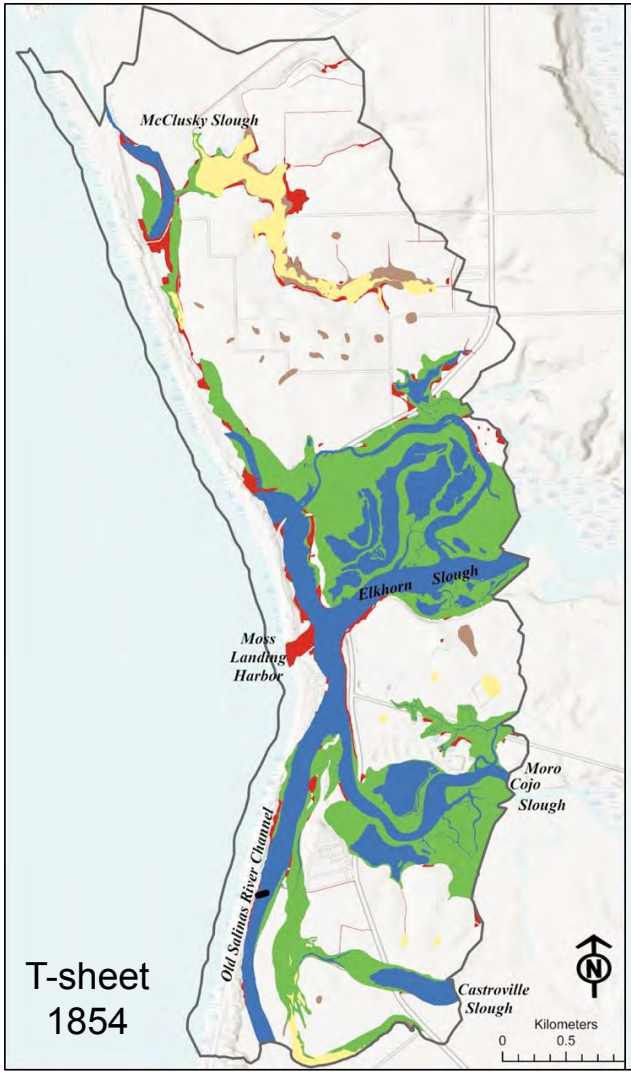


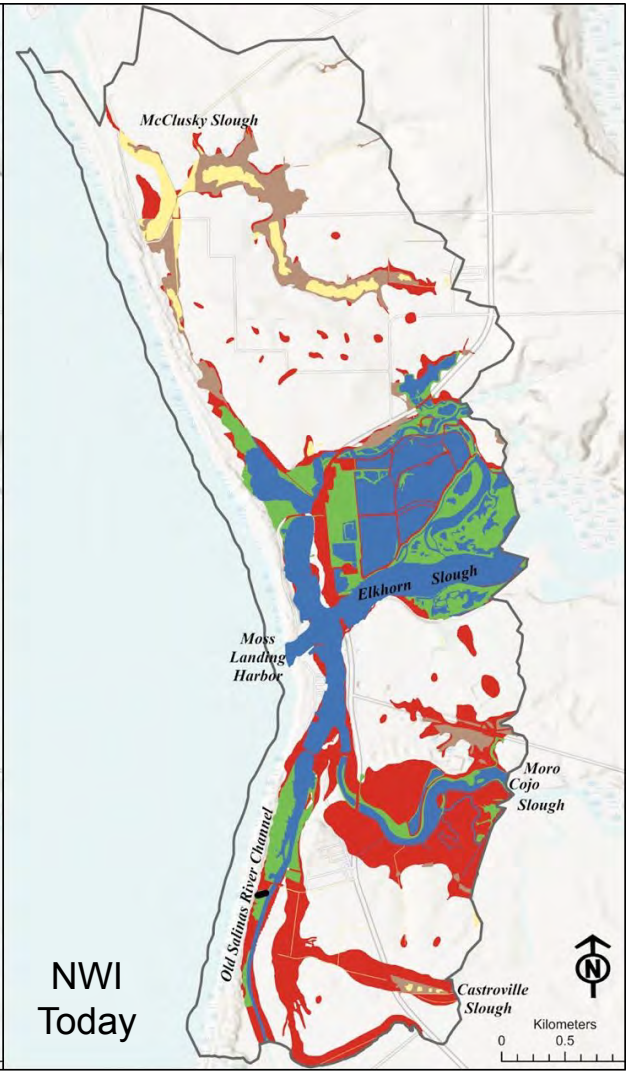
FIGURE 50.—Conventional symbols used in 1865.


Elkhorn Slough's 1854 T-sheet
Salt marsh
Sand
Freshwater pond
Tide line (MLLW)
Grass
Tide flat
Salt Pan
Estero Grande or Roadhouse Slough
Bennett's Slough
Gibson's Landing
Ferry
SALINAS
PART


A
B
McClusky Slough
Elkhorn Slough
Moro Cojo Slough
0 0.38 0.75 1.5 Kilometers
Habitat
Subtidal water
Intertidal, no plants
Tidal marsh
Tidal marsh, brackish
Sand
Freshwater lake/pond
Freshwater marsh
Wet meadow
Grassland
Tree
Developed

COMPARE PAST AND PRESENT





Resources for you

REPORTS

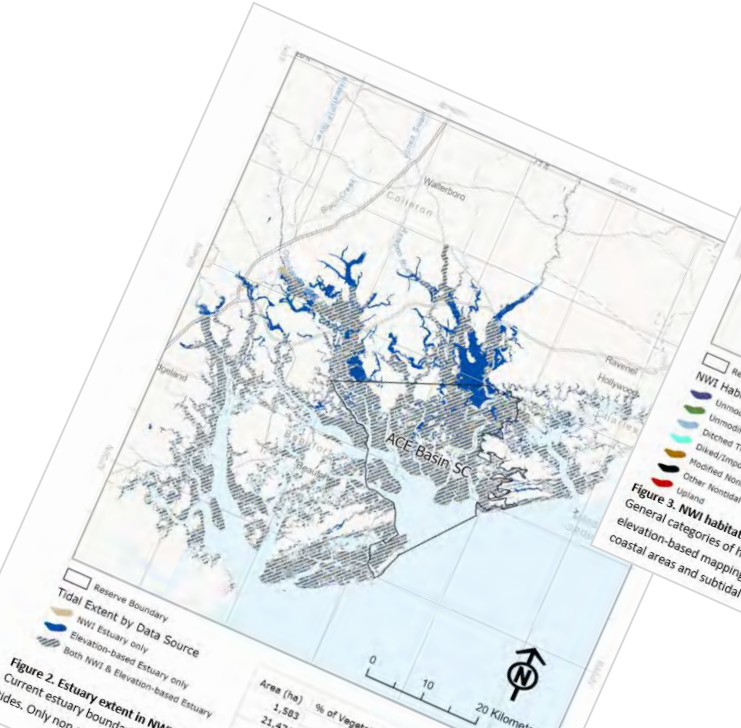
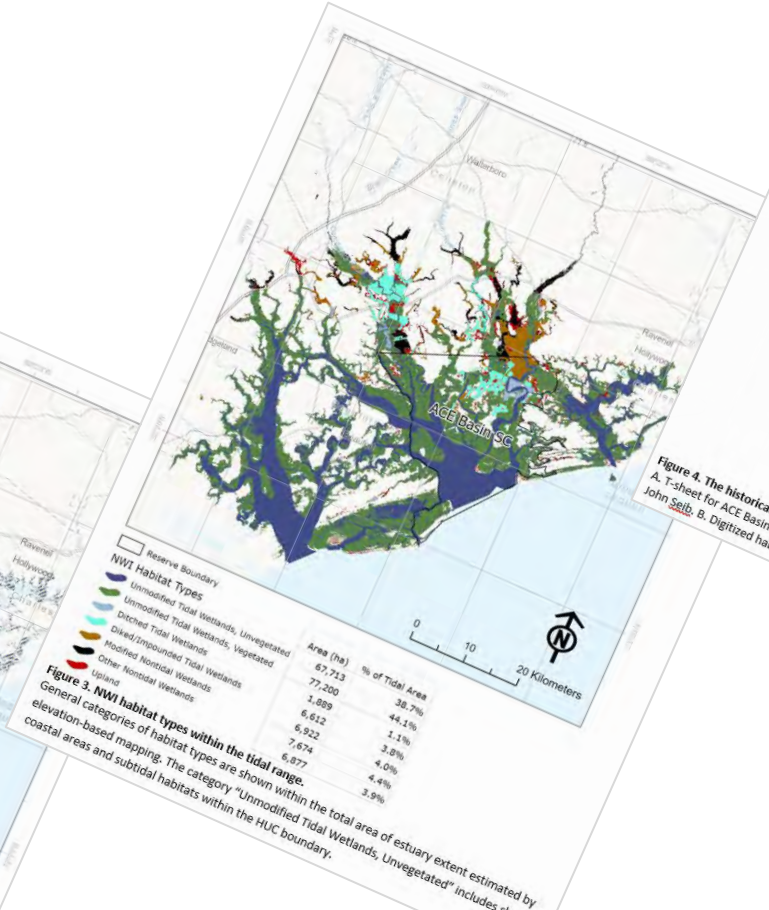


Figure 2. Estuary extent in NW
Current estuary bound
ides. Only non



	Area (ha)	% of Tidal Area
	67,713	
	77,200	38.7%
	1,889	44.1%
	6,612	1.1%
	6,932	3.8%
	7,674	4.0%
	6,877	4.4%
		3.9%

Figure 3. NWI habitat types within the tidal range. General categories of habitat types are shown within the total area of estuary extent estimated by elevation-based mapping. The category "Unmodified Tidal Wetlands, Unvegetated" includes coastal areas and subtidal habitats within the HUC boundary.

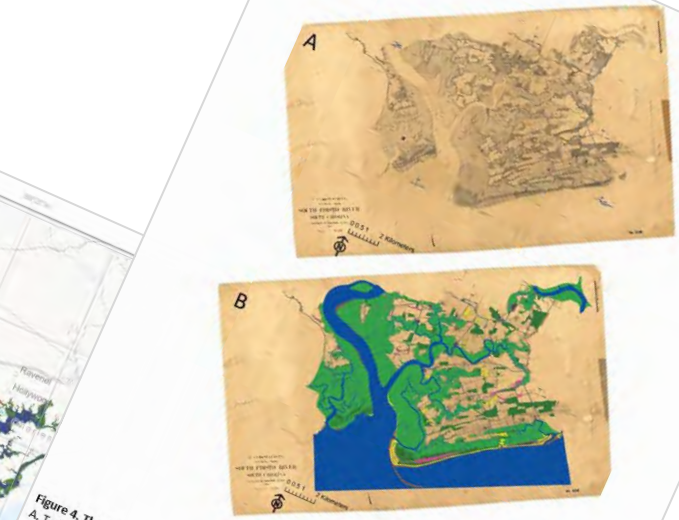


Figure 4. The historical map and its digitization used for this estuary. A. T-sheet for ACE Basin NERR, T508, *South Edisto River, South Carolina*, based on a 1852 survey led by John Seib. B. Digitized habitats, including both wetlands and uplands.

BRIEFS

Mapping a new vision for our estuaries

Estuaries are subject to change. Where have they been, where are they now, and where may they be in the future? How have their habitats changed over time? A team led by the National Estuarine Research Reserve System (NERRS) explored those questions in 30 estuaries around the country.

For each estuary, the research team mapped areas within the potential reach of tides, including those places that are currently disconnected and may hold opportunities for restoration. They found clear regional differences in how estuaries have changed since the 1800s and identified which habitat types underwent the greatest loss.

For example, net loss of estuarine habitat is ubiquitous on the West Coast (primarily due to diking), but habitat extent has been more stable elsewhere. Nationally, the majority of estuaries have lost tidal marshes, but in some Gulf of Mexico and East Coast estuaries, these habitats have advanced landward, causing the loss of forested wetlands or uplands.

The elevation-based mapping and historical mapping techniques used in this study were effective across the wide range of geographies represented by the Reserve System, illustrating their usefulness in future studies anywhere in the world.

Why map estuaries?

Healthy estuaries are economic powerhouses and essential to the well-being of coastal communities. Over time, however, diking, farming, and other kinds of development have changed the extent of some estuaries, shrinking their habitats and making them less productive. Conversely, in other areas, sea-level rise has pushed tidal marshes landward, displacing tidal forests, nontidal forested wetlands, or uplands.

Accurate mapping of estuarine habitats is critical for successful conservation and restoration. However, current maps often do not reflect the extent of tidal wetlands, especially those that are forested. Understanding an estuary's past extent—an indication of where it could be again—is even more challenging, but important to setting restoration goals. In the face of changing water levels and land uses, understanding the extent of an estuary and its habitats is critical to decisions of where and how to invest limited resources.

Discovering an estuary's extent

To sleuth which areas are within the potential reach of the tides, the NERRS team combined tidal- and land-elevation data in a technique known as **elevation-based mapping**—a powerful way to visualize where the estuary is today, where it was, and where it could be were artificial barriers to tides removed.

The team also conducted **historical mapping** using "T sheets" (topographic sheets) from 1846 to 1920, which show the distribution and extent of estuarine habitats in times with less development. This yielded maps that can be used, for example, to help identify areas for restoration of habitat types that were once common, but are now rare.

Mission-Aransas Reserve

Past, present, and future

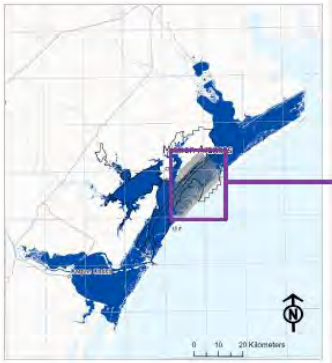
Tidal wetlands in and around Texas' Mission-Aransas Reserve and the Corpus Christi/San Antonio Bay System have been dynamic over time. Estuarine wetlands are still extensive, with relatively few net losses and significant gains where historically upland areas have converted to tidal wetlands. Conserving and restoring these habitats and providing potential migration pathways for them are key priorities, so they can continue to support clean water, create habitat for fish and wildlife, invite outdoor recreation, and boost local economies. The new information from this habitat change analysis will develop a collective vision for a more resilient coast that can be enjoyed by generations to come.

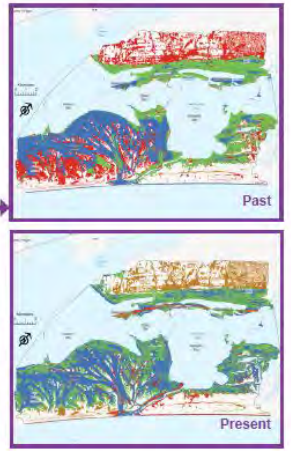
Area within reach of tides

Elevation-based mapping revealed an extensive area of interconnected channels and wetlands within the range of tides. However, it failed to identify high elevation areas as tidal wetlands, even though local expertise indicates these areas are occasionally flooded by tides. Other areas identified by elevation but not the USFWS National Wetland Inventory merit further study to determine whether they are functioning as tidal wetlands.

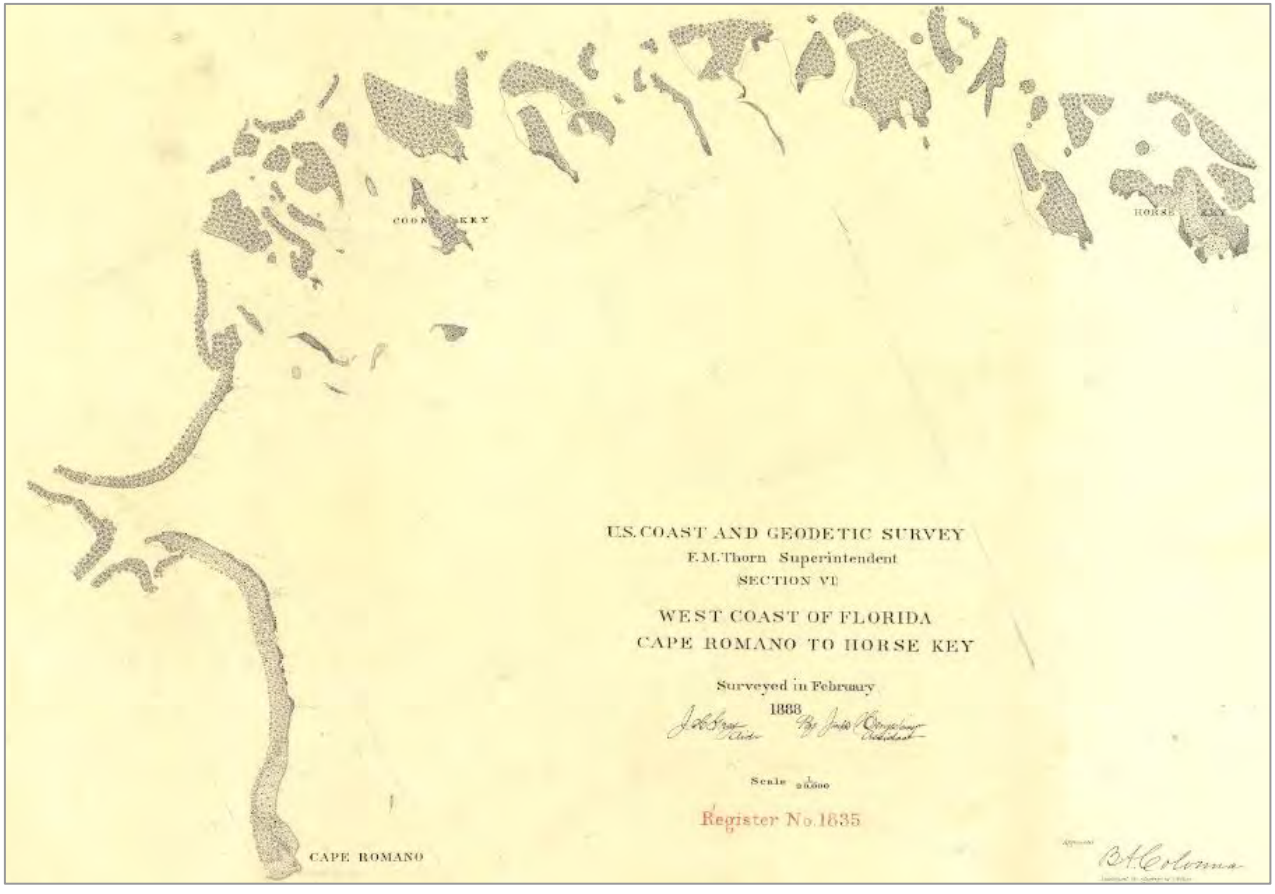
Habitat changes over time

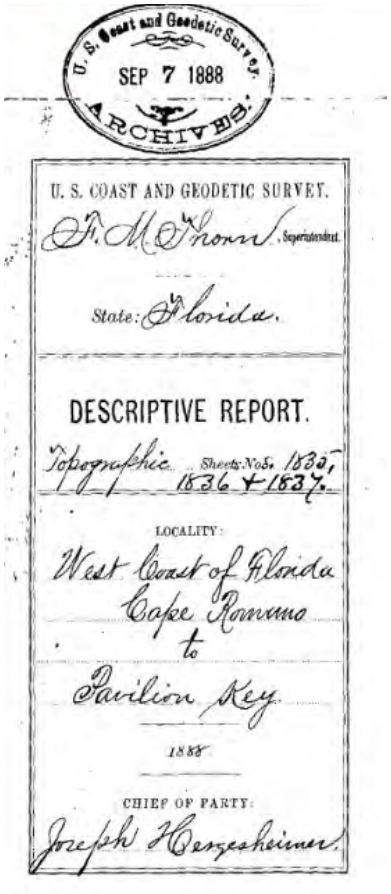
An analysis comparing a historical map from 1860 to the present revealed that habitat distribution has been extremely dynamic over time. There has been significant conversion of uplands (**red**) to tidal (**green**) and nontidal (**brown**) vegetated wetlands. Some of the apparent conversion may be due to a lack of thoroughness in past surveys, but others definitely occurred, as evidenced by marshes migrating upland. In other areas, vegetated tidal wetlands (**green**) have converted to unvegetated tidal wetlands (**blue**).



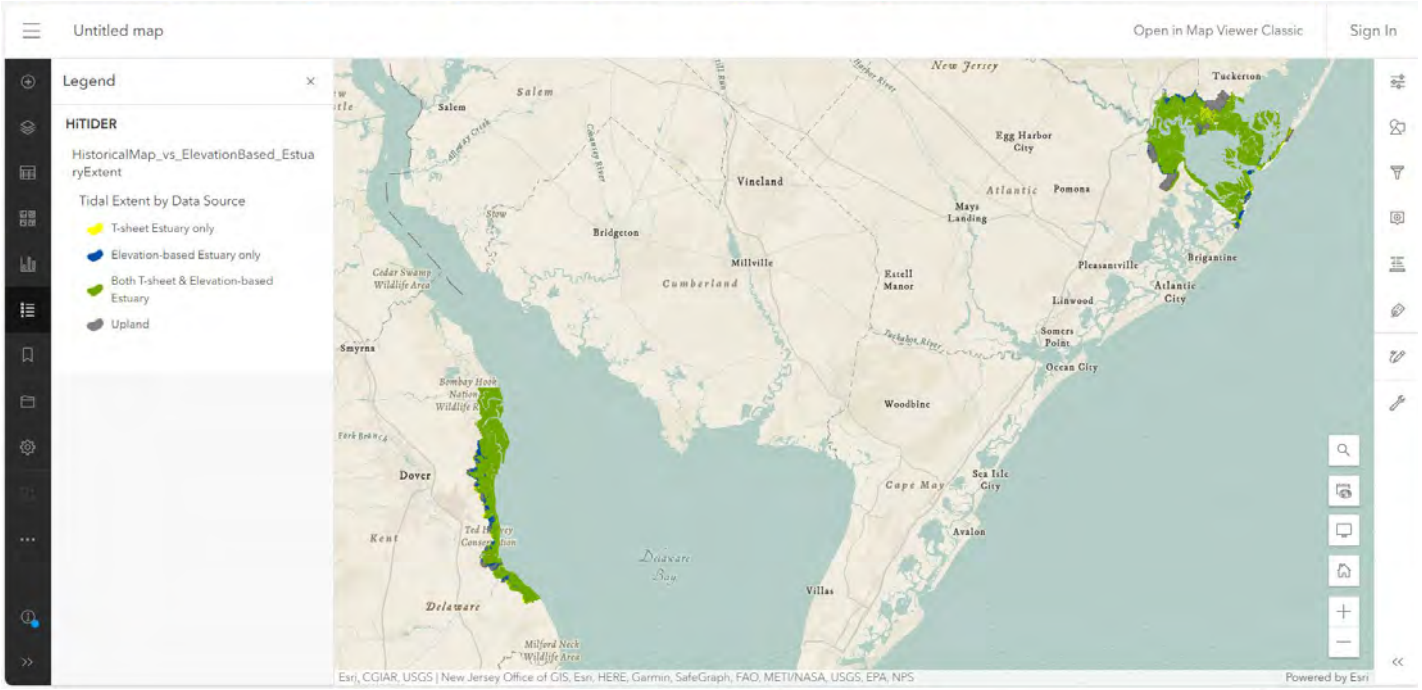


ORIGINAL SURVEYS & REPORTS





GIS DATA



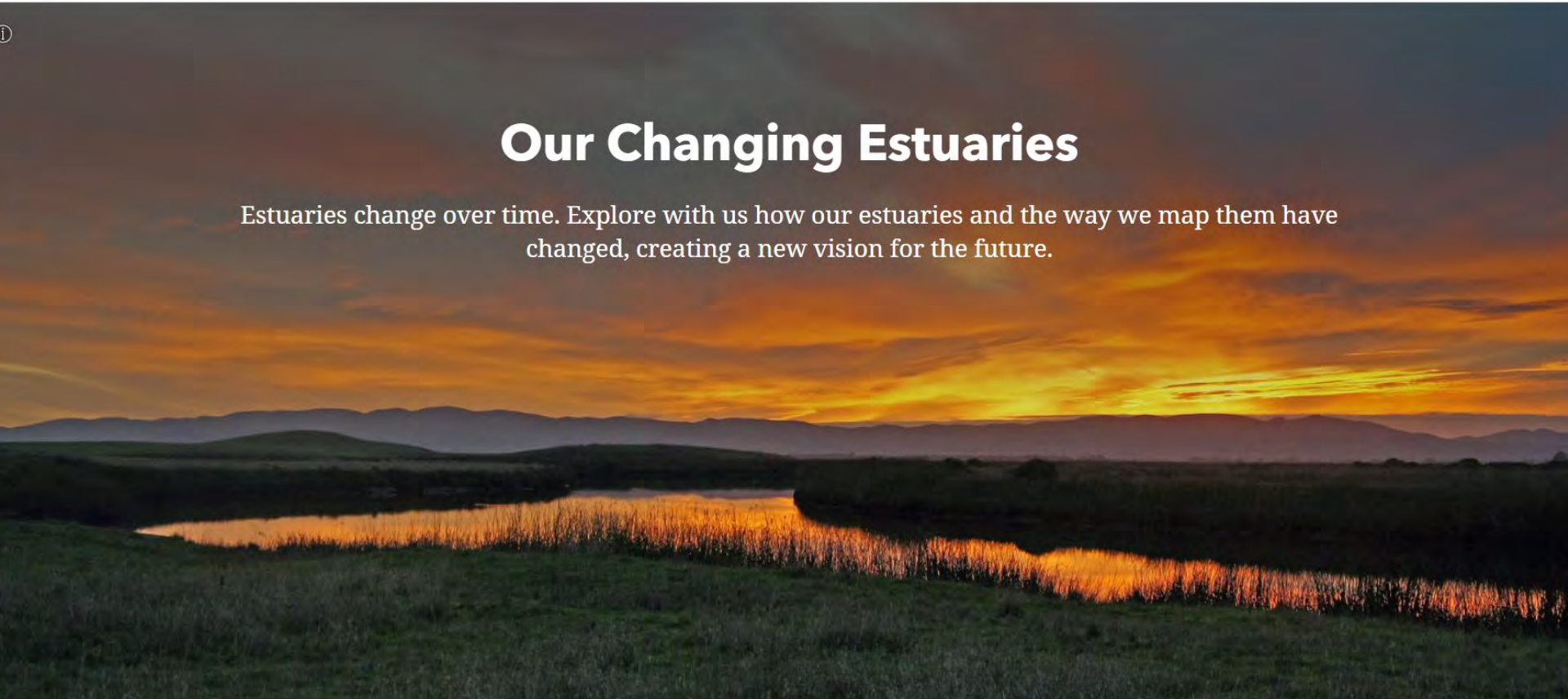
AGOL.

Downloads.

Name	Owner	Last modified	File size
Estuary Change GIS Data	Melissa Ide (CDMO)	Nov 2, 2023 Melissa Ide (C...	—
Estuary Change Reserve Reports	Melissa Ide (CDMO)	Nov 2, 2023 Melissa Ide (C...	—
Historical Maps	Melissa Ide (CDMO)	Oct 19, 2023 Melissa Ide (C...	—

GIS METHODS TRAINING
FEBRUARY 14, 2024

STORY MAP


Our Changing Estuaries
Estuaries change over time. Explore with us how our estuaries and the way we map them have changed, creating a new vision for the future.

Collection

Reserve stories

Explore the historical analysis and elevation-based mapping results for each reserve.

Get started

1. ACE Basin
2. Apalachicola
3. Chesapeake Bay, Maryland
4. Chesapeake Bay, Virginia
5. Connecticut
6. Delaware
7. Elkhorn Slough
8. Grand Bay
9. Great Bay
10. Guana Tolomato Matanzas
11. He'eia
12. Hudson River
13. Jacques Cousteau
14. Jobos Bay

1 Ashepoo-Combahee-Edisto (ACE) Basin

2 Apalachicola

3 Chesapeake Bay - Maryland

4 Chesapeake Bay - Virginia

5 Connecticut

6 Delaware

7 Elkhorn Slough

8 Grand Bay

9 Great Bay

10 Guana Tolomato Matanzas

11 He'eia

12 Hudson River

Padilla Bay

National Estuarine Research Reserve

September 25, 2023

Located in northwestern Washington state and including 4,842 hectares (11,966 acres), the Padilla Bay National Estuarine Research Reserve was established in 1980 and is managed in partnership between the National Oceanic and Atmospheric Administration (NOAA) and the Washington Department of Ecology, with support from the Padilla Bay Foundation.

Padilla Bay, Washington

TIDAL MARSH CHANGE

Tidal Wetlands
- Vegetated
- Unvegetated

Nontidal Wetlands
- Vegetated
- Unvegetated

- Upland
- T-sheet Area of Interest

Padilla Bay, Washington

TIDAL MARSH CHANGE

Tidal Wetlands
- Vegetated
- Unvegetated

Nontidal Wetlands
- Vegetated
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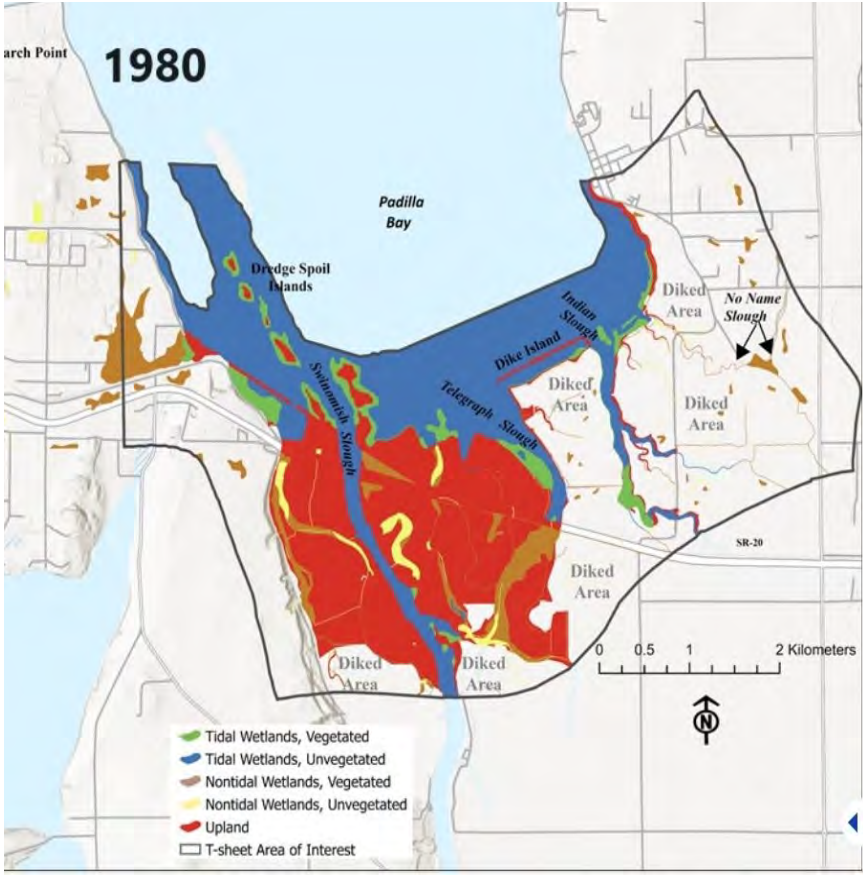
- Upland
- T-sheet Area of Interest



Why map estuaries?

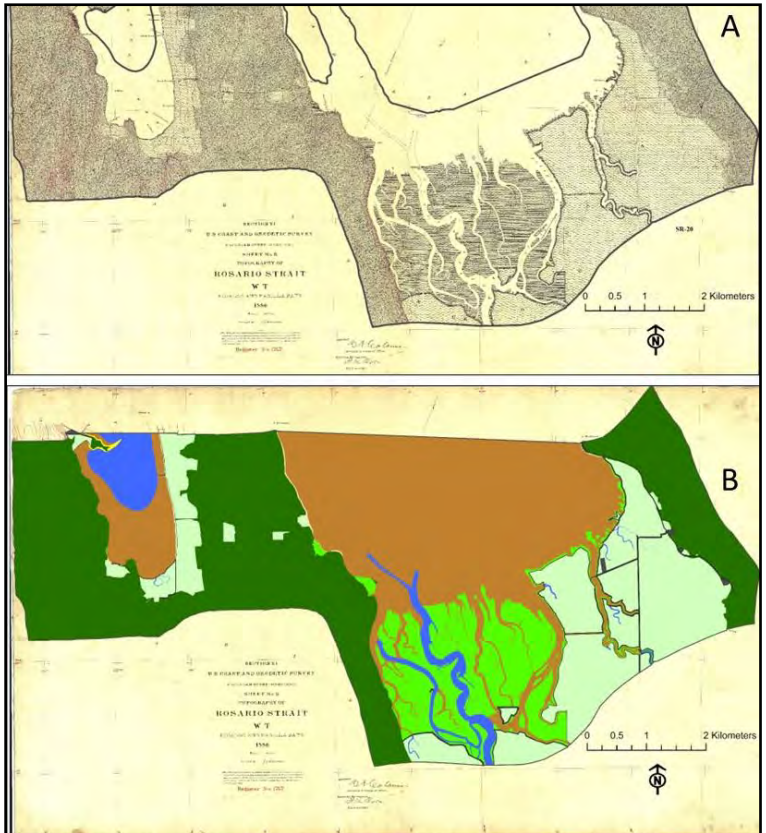
How?

What did we learn?


LESSONS LEARNED
PAST
PRESENT
CHANGE
FUTURE
Padilla Bay
South Slough
San Francisco Bay
Elkhorn Slough
Los Angeles
Tijuana River
Phoenix
Lake Superior
Chicago
Old Woman Creek
Toronto
Montreal
Hudson River
Wells
Great Bay
Narragansett Bay
Waquoit Bay
Connecticut
Jacques Cousteau
Delaware
Chesapeake Bay MD
Chesapeake Bay VA
North Carolina
North Inlet Winyah Bay
ACE Basin SC
Sapelo Island
Guana Tolomato Matanzas
Grand Bay
Weeks Bay
Apalachicola Bay
Rookery Bay
San Antonio
Houston
Mission-Aransas
Monterrey

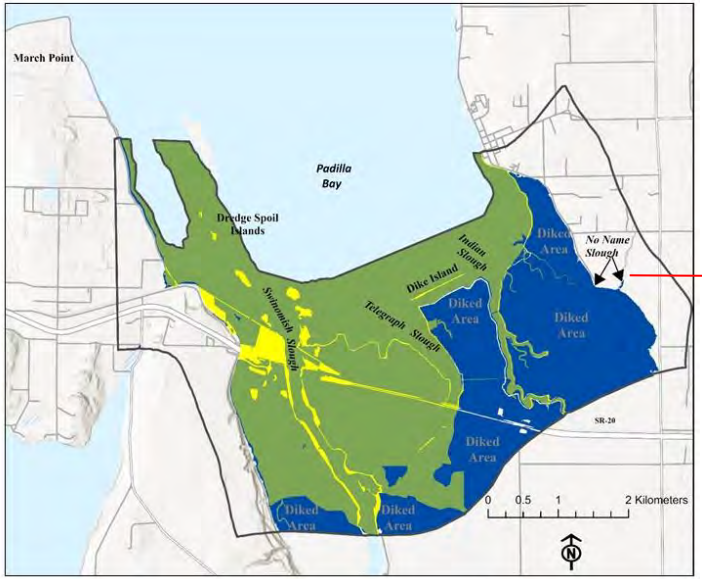
PAST

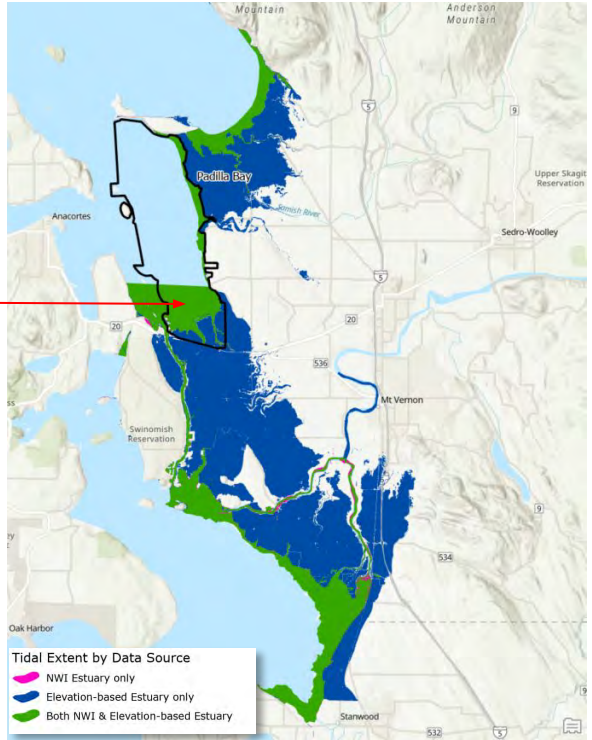
Historical maps shed light on past habitat distribution



PAST

Elevation-based mapping complements historical maps: deeper baseline, broader spatial scale, focus on tides





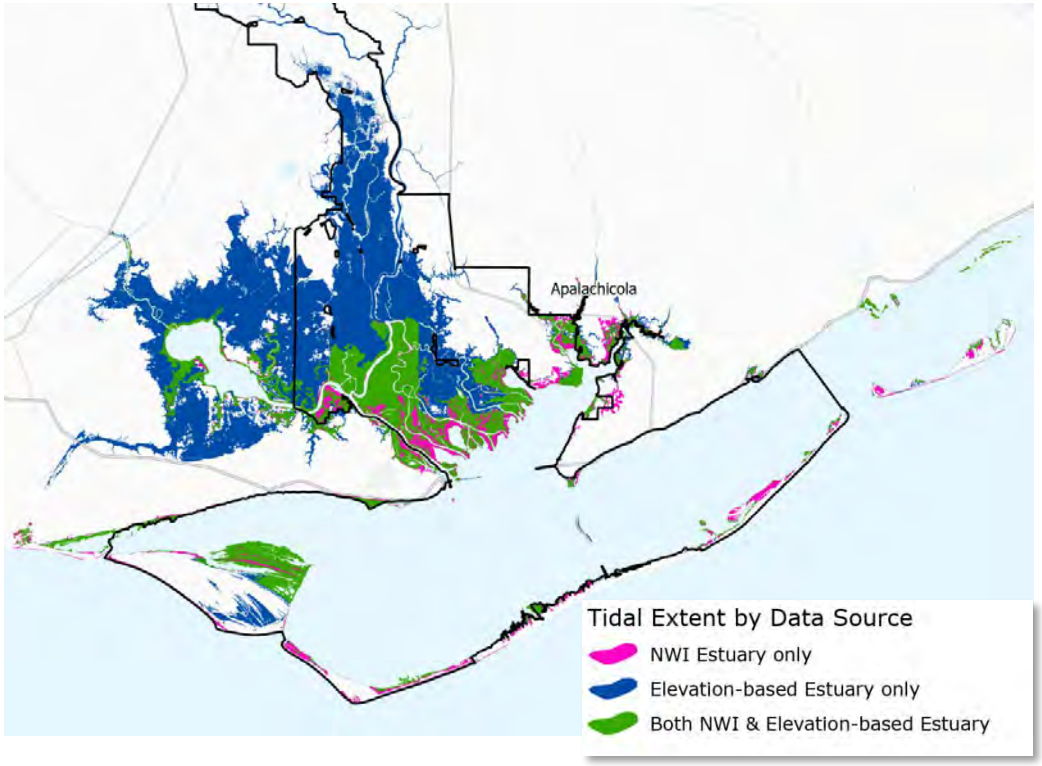
LESSONS LEARNED

- PAST
- PRESENT
- CHANGE
- FUTURE

PRESENT

Elevation-based mapping reveals larger estuary

detected estuarine habitats missed by NWI at 93% of estuaries – often extensive areas



PRESENT

Tidal forests in particular are often missed by NWI:

at 82% tidal estuaries, elevation-based mapping detected tidal forests missed by NWI

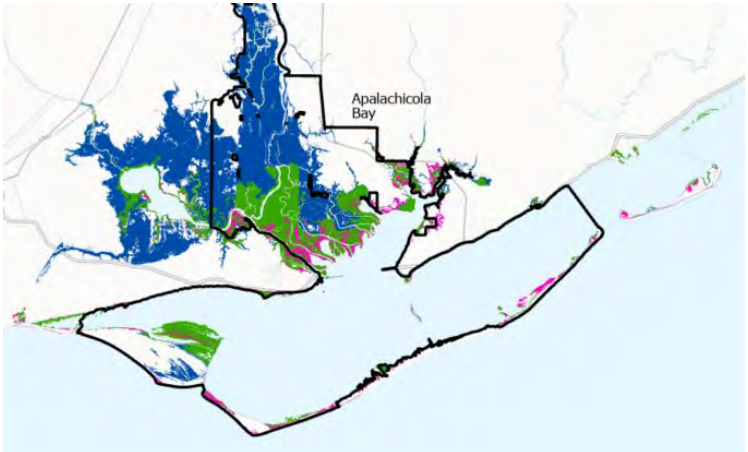
LESSONS LEARNED

- PAST
- PRESENT
- CHANGE
- FUTURE

CHANGE IN ESTUARY EXTENT

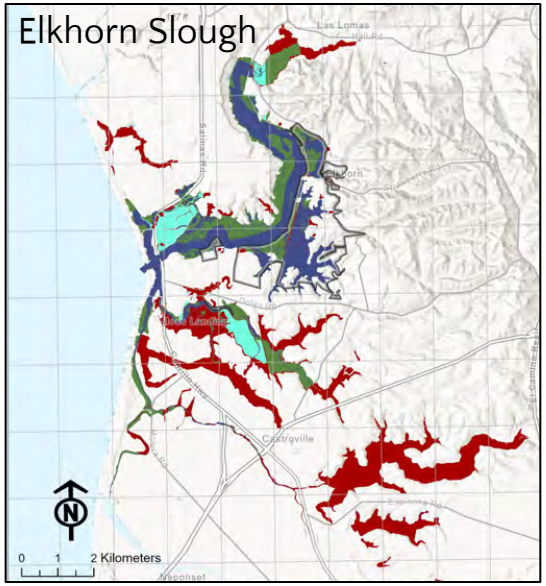
Unexpected problems conducting change analyses

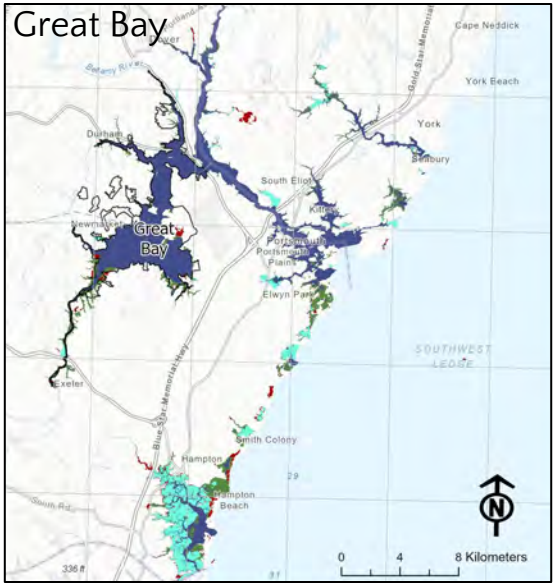
At 21/28 tidal estuaries, could not conduct formal change analyses, mostly because NWI did not accurately map current estuary



CHANGE IN ESTUARY EXTENT

Much more loss on Pacific coast





Pacific coast

4 estuaries

average **74% loss** of vegetated estuary

range 61–84%

Other coasts

3 estuaries

average **7% loss** of vegetated estuary

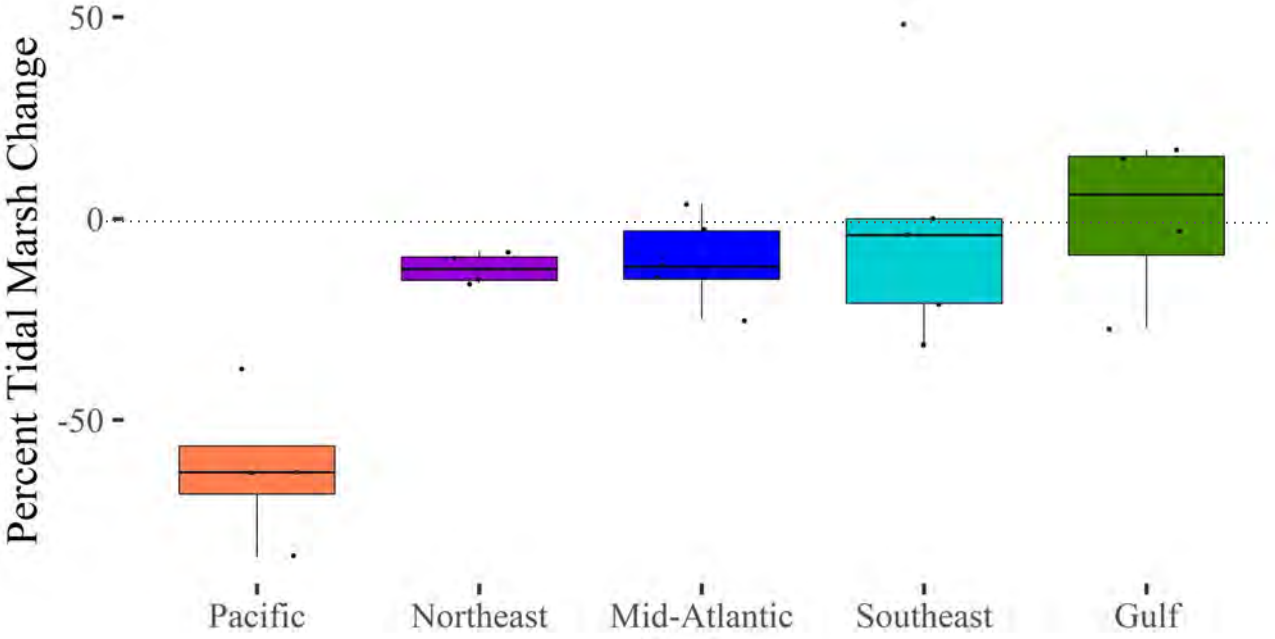
range 3–12%

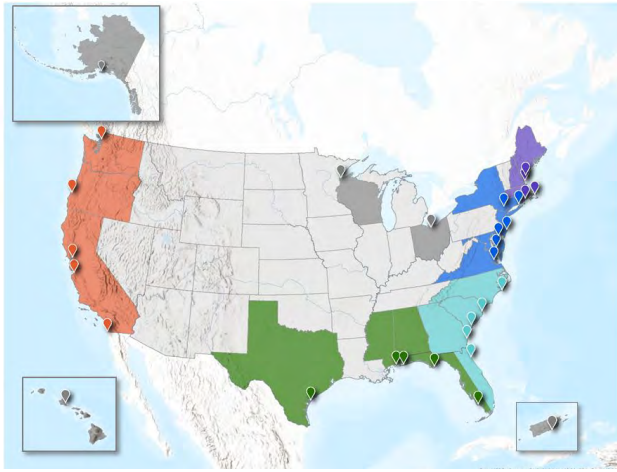
CHANGE

Tidal marsh was well-mapped in both historical maps and NWI, so we could conduct change analysis

CHANGE

Comparing tidal marsh extent in historical maps vs. NWI revealed greatest loss on Pacific coast



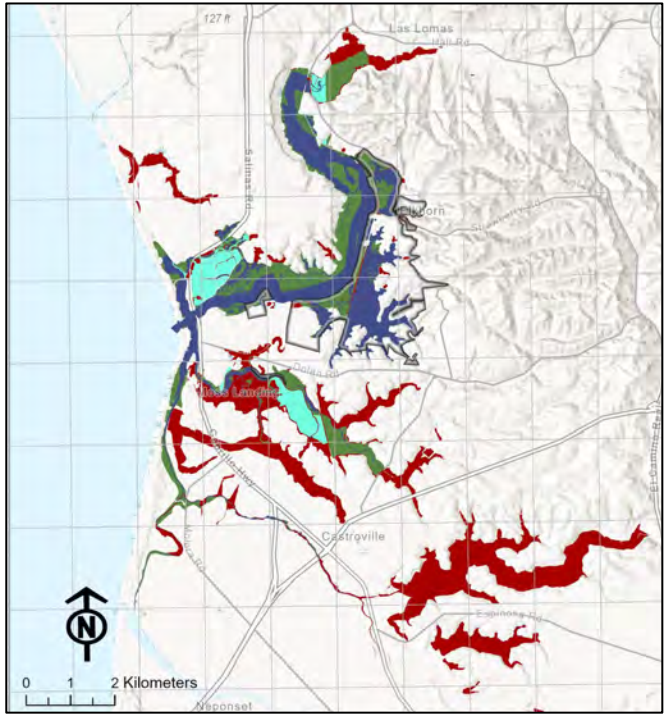


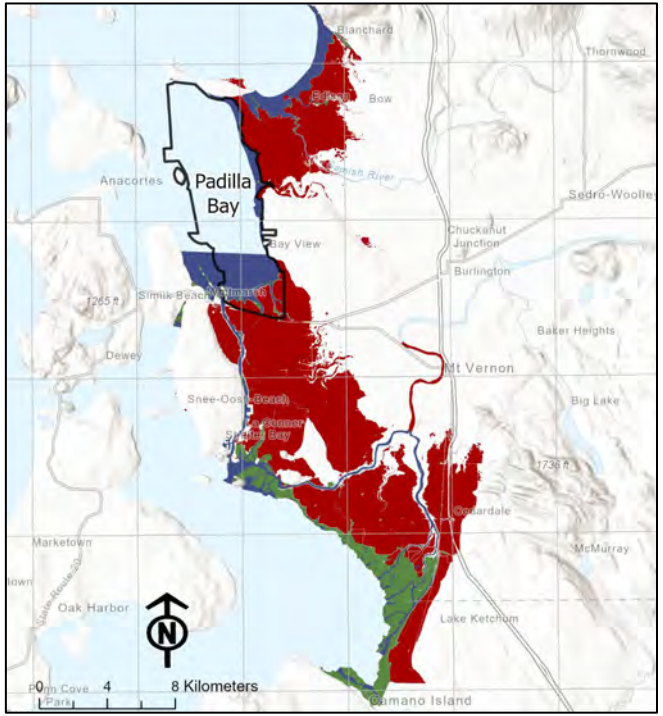

LESSONS LEARNED
PAST
PRESENT
CHANGE
FUTURE
Padilla Bay
South Slough
San Francisco Bay
Elkhorn Slough
Los Angeles
Tijuana River
Phoenix
Lake Superior
Chicago
Old Woman Creek
Toronto
Montreal
Hudson River
Wells Great Bay
Narragansett Bay
Waquoit Bay
Connecticut
Jacques Cousteau
Delaware
Chesapeake Bay MD
Chesapeake Bay VA
North Carolina
North Inlet Winyah Bay
ACE Basin SC
Sapelo Island
Guana Tolomato Matanzas
Grand Bay
Weeks Bay
Apalachicola Bay
Rookery Bay
Mission-Aransas
San Antonio
Houston
Monterrey

FUTURE

Tidal wetland extent can be restored:

on Pacific especially, lots of lost estuary to be regained





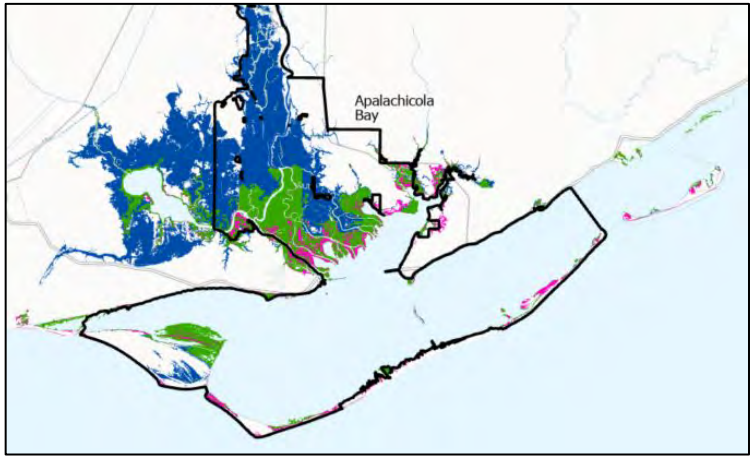
A bigger estuary supports more fishing, protects more shorelines, sequesters more carbon, offers more recreation….

Atchafalaya, Louisiana (NERR Photos)

FUTURE

Tidal forests need more attention:

poorly known; many at risk of becoming ‘ghost’ forests



FORWARD-LOOKING APPLICATIONS

Using habitat change analyses for climate adaptation planning: San Diego example

Historical Wetlands of the Southern California Coast

AN ATLAS OF US COAST SURVEY T-SHEETS, 1851-1889

Robin Grossinger[1], Eric D. Stein[2], Kristen Cayce[1], Ruth Askevold[1], Shawna Dark[3], Alison Whipple[1]

[1]San Francisco Estuary Institute (SFEI)

[2]Southern California Coastal Water Research Project (SCCWRP)

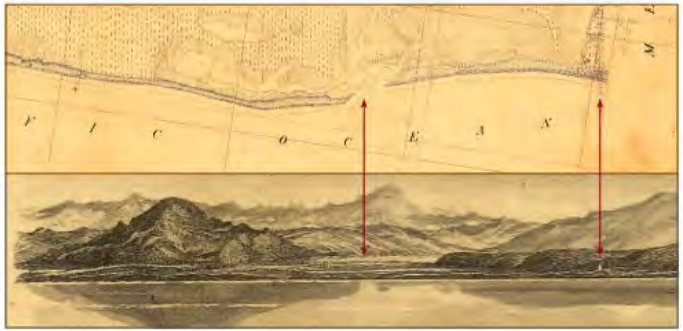
[3]California State University Northridge (CSUN)

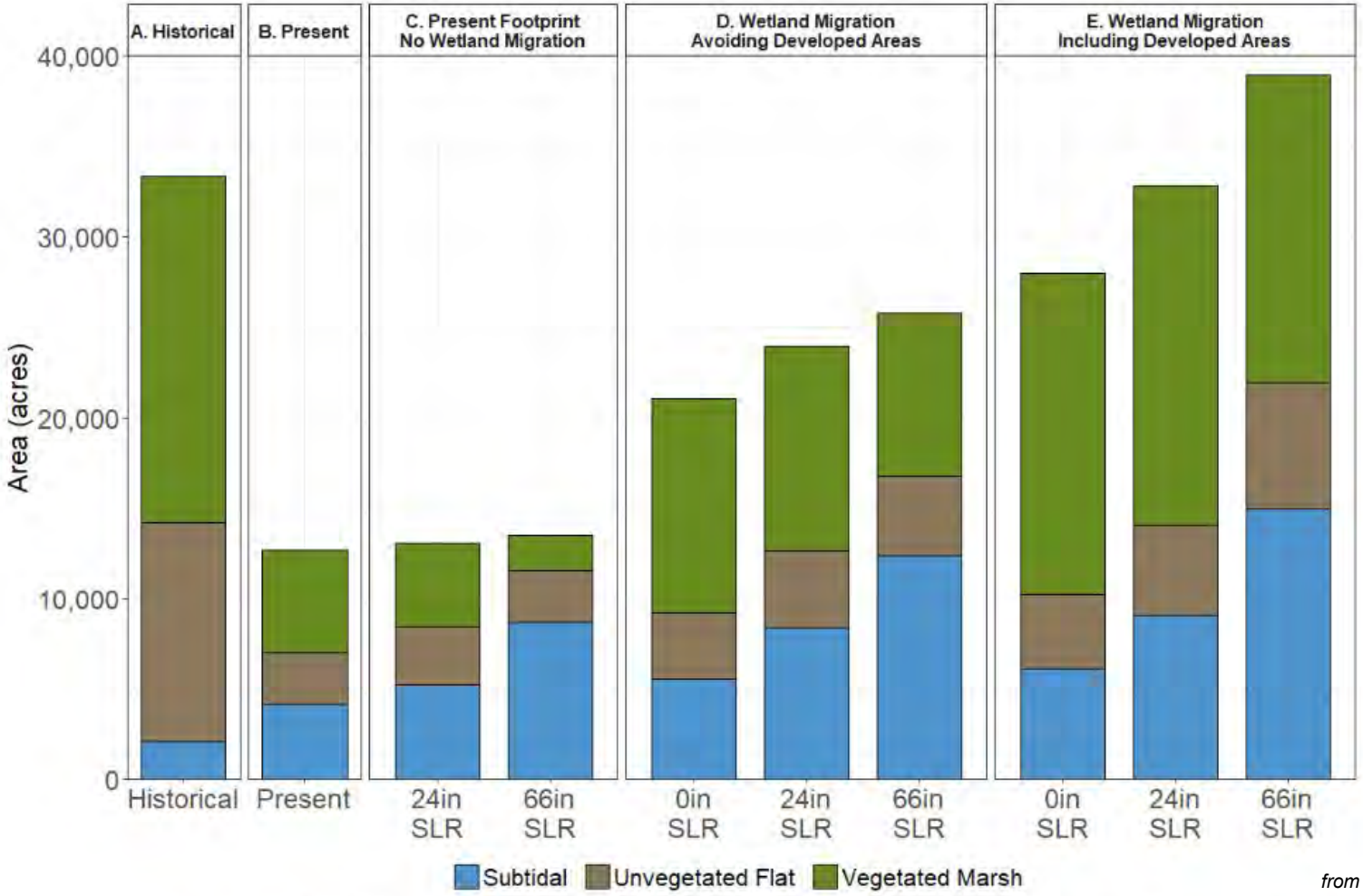
JANUARY 2011

SFEI
CONTRIBUTION NO. 586

SCCWRP
SCCWRP TECHNICAL REPORT NO. 589

Funded by the STATE OF CALIFORNIA Coastal Conservancy

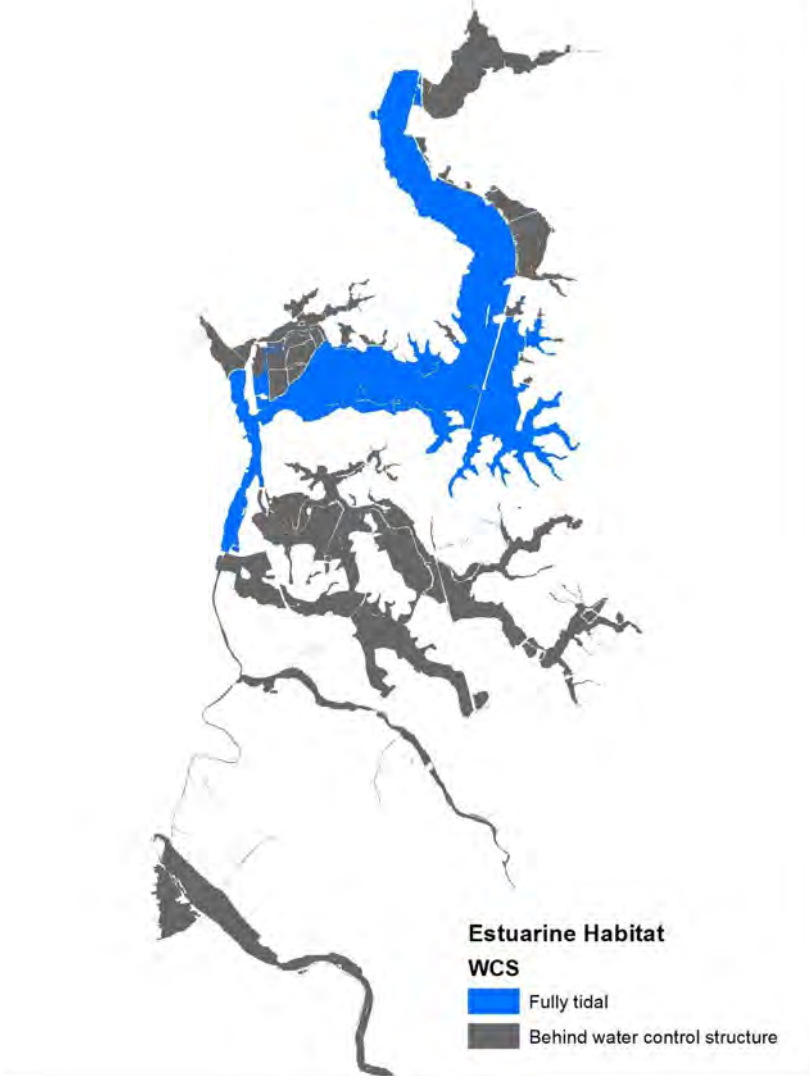




from WRP Regional Strategy - 2018
https://scwrp.databasin.org/

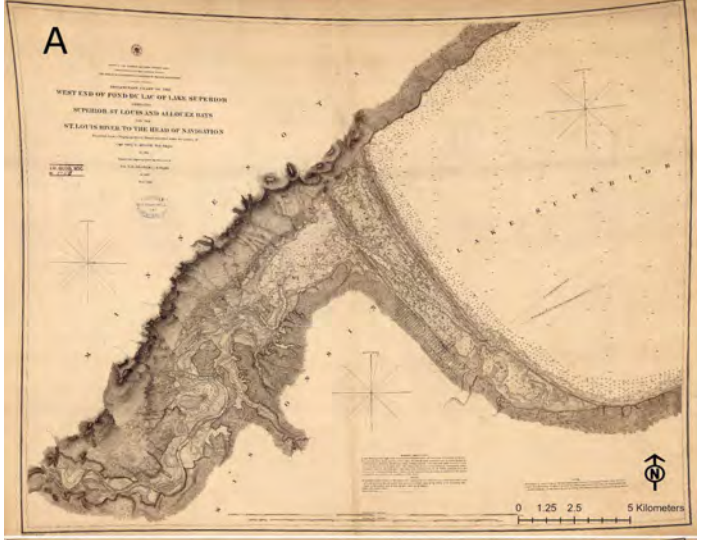
Restoration projects motivated by understanding past loss: Elkhorn example

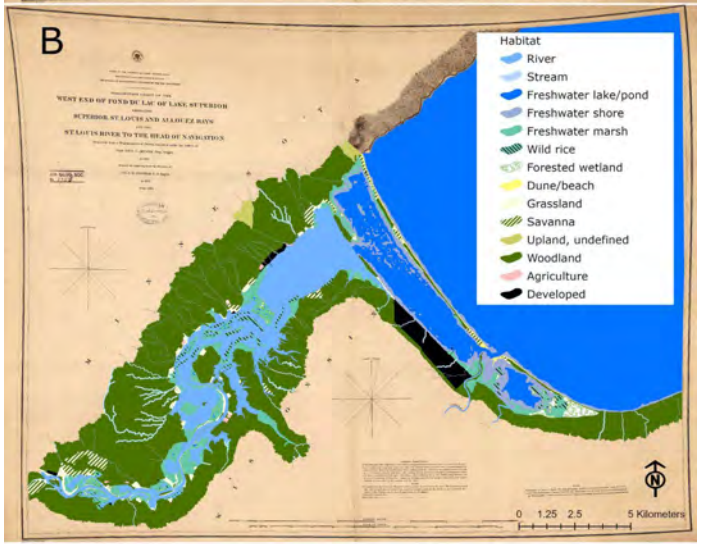
Understanding how vast the past estuary was helps us to think big and avoid problems of shifted baselines



Using habitat mapping to support cultural services: Lake Superior NERR wild rice

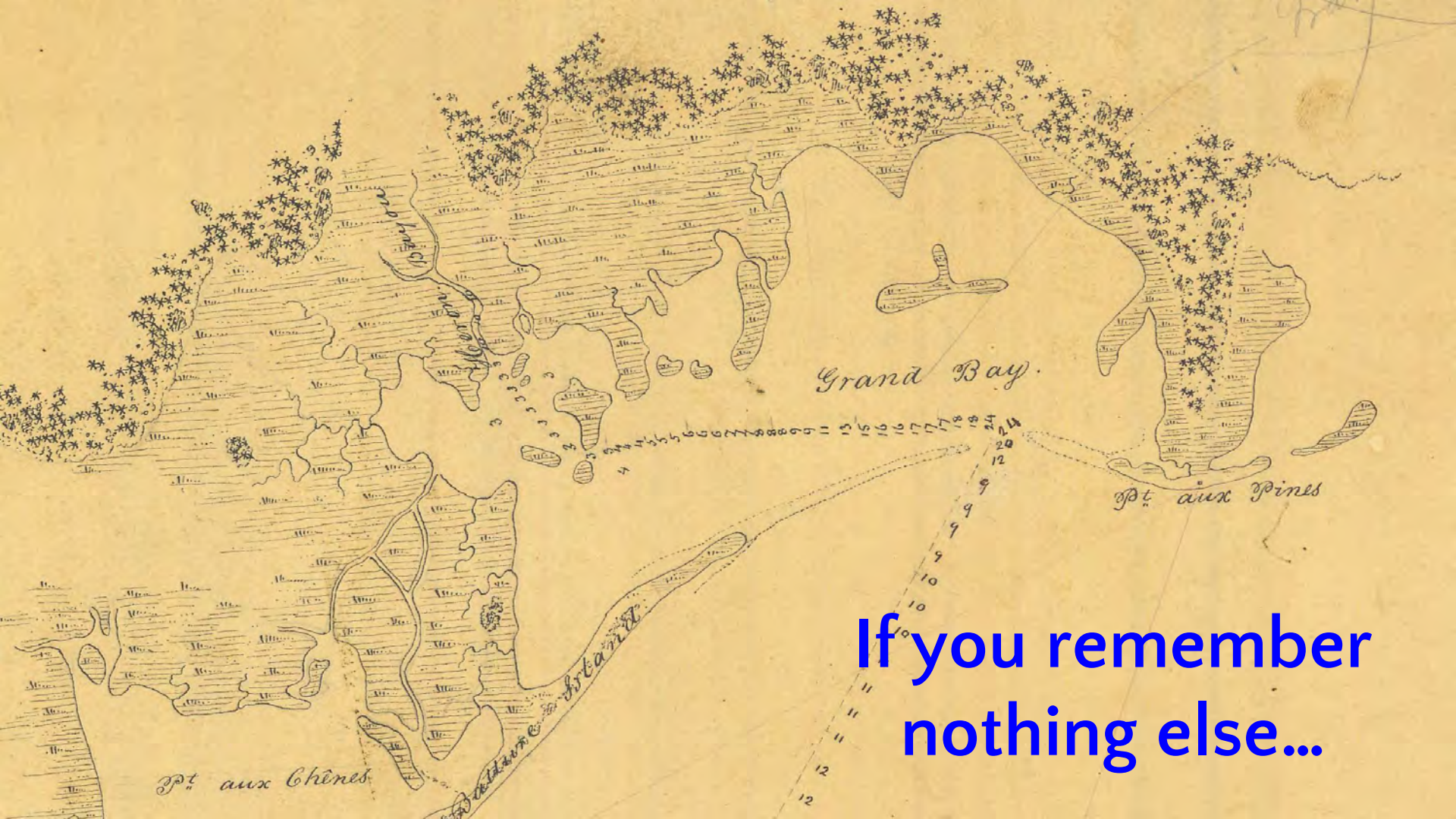
Historical maps identify areas for cultural restoration of *manoomin*





Using habitat mapping for education:
Elkhorn Slough example

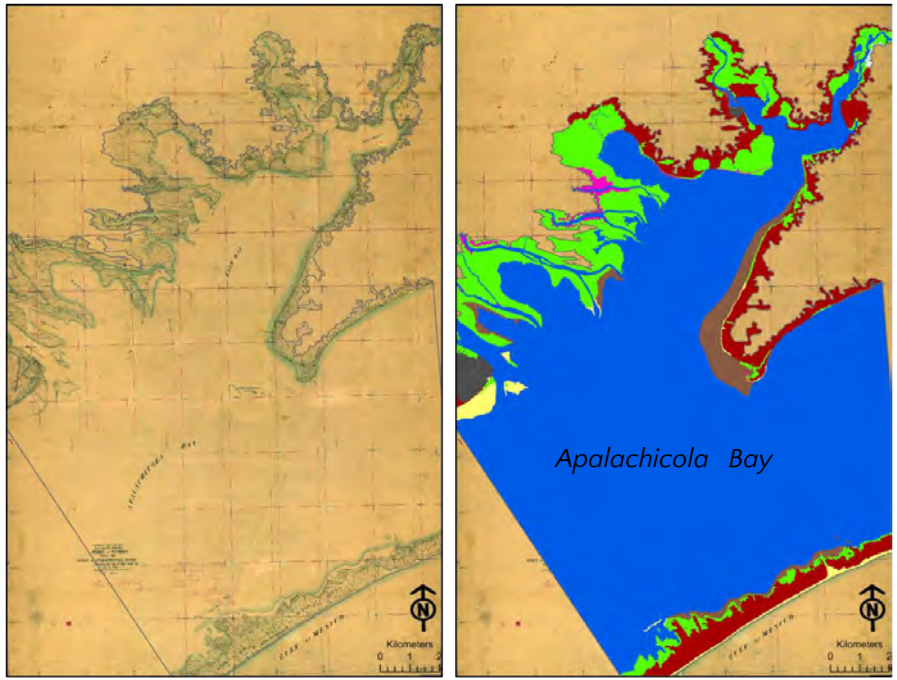
Interactive touch screen with historical ecology of estuary

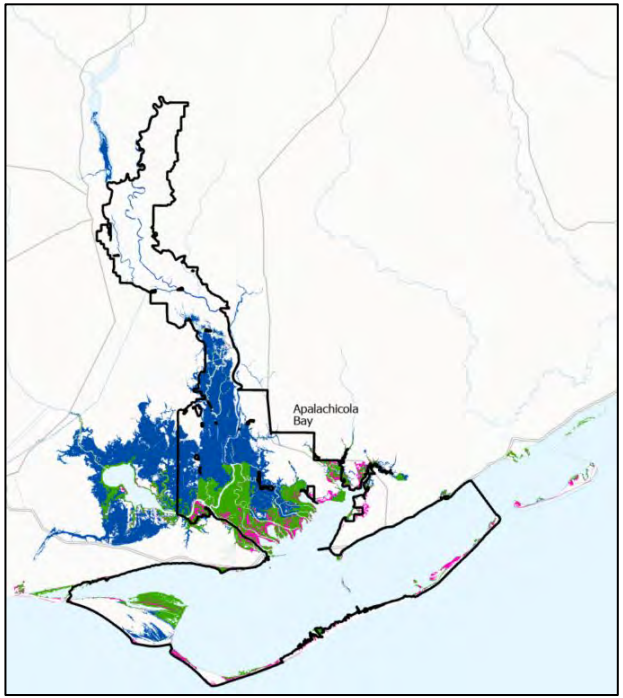


If you remember nothing else...

MULTIPLE MAPPING METHODS

Complement each other, and together are more accurate than any single approach



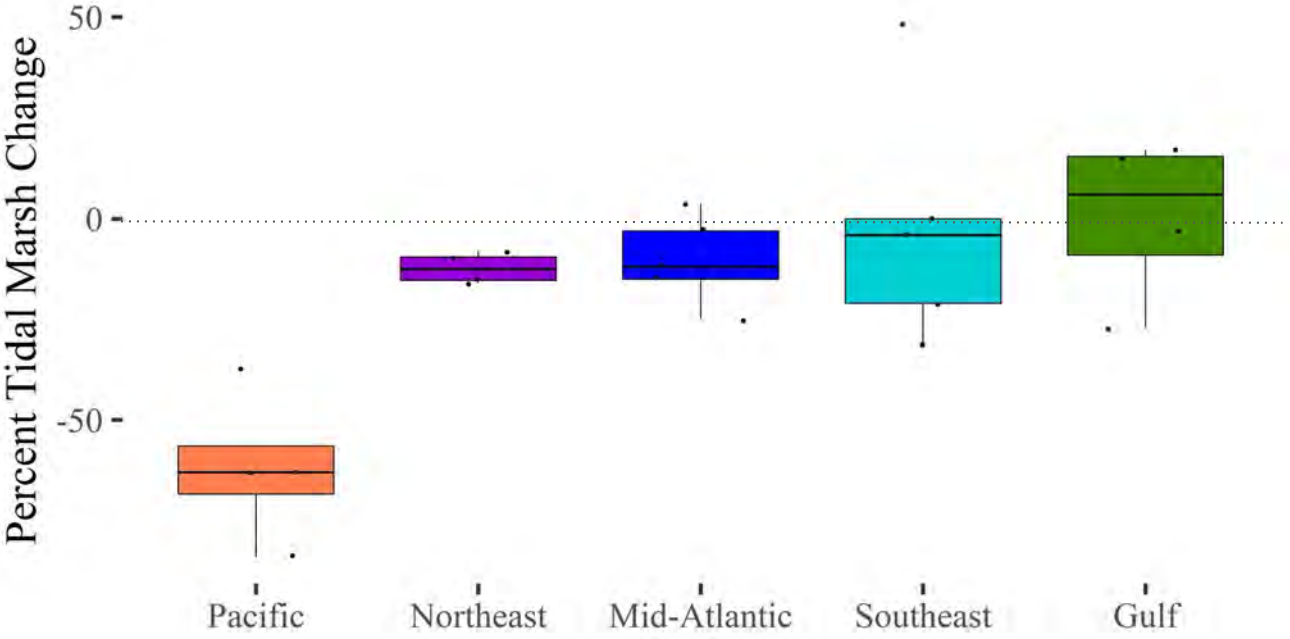


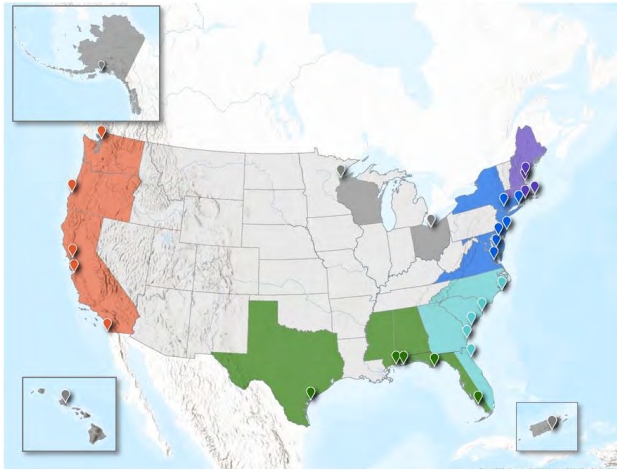
TIDAL FORESTS

Temperate tidal swamps need a lot more love

REGIONAL DIFFERENCES

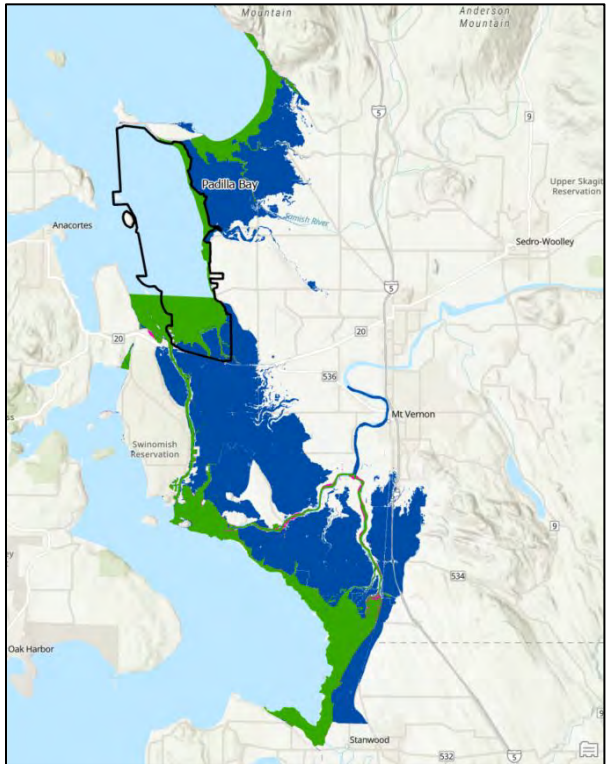
Different coastal resilience strategies needed in different geographic areas

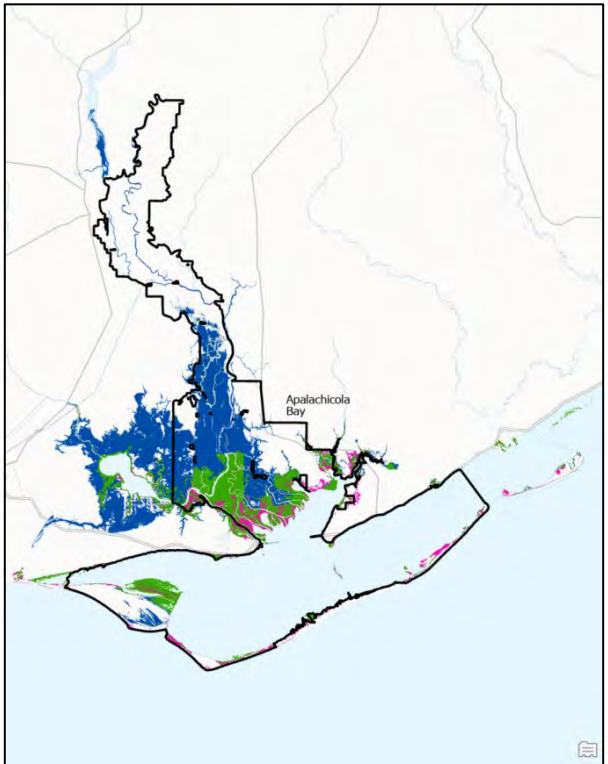




THINK BIG

Our estuaries are bigger than we think they are, and they could be bigger still





Understanding where our estuaries are, were, and could be will help us take better care of them

see **https://www.nerra.org/estuary-change** to access all products and register for training