Bringing back underwater prairies: the science of restoring eelgrass ecosystems *Highlights and Lessons Learned*

Christopher J. Patrick, Ph.D.

LIS Eelgrass Collaborative Meeting

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cpatrick@vims.edu

https://www.vims.edu/research/units/labgroups/ceel/index.php

Coastal Productivity

Coastal Productivity

Seagrass meadows are some of the most widespread and productive coastal habitats worldwide.

What is seagrass?

Seagrasses are a group of
Submersed Aquatic Vegetation

<u>Vascular</u> flowering plants we find growing underwater in aquatic environments (freshwater, estuarine, and marine).

Seagrasses are SAV living in saltwater that descended from terrestrial plants that invaded the marine environment 100 mya.

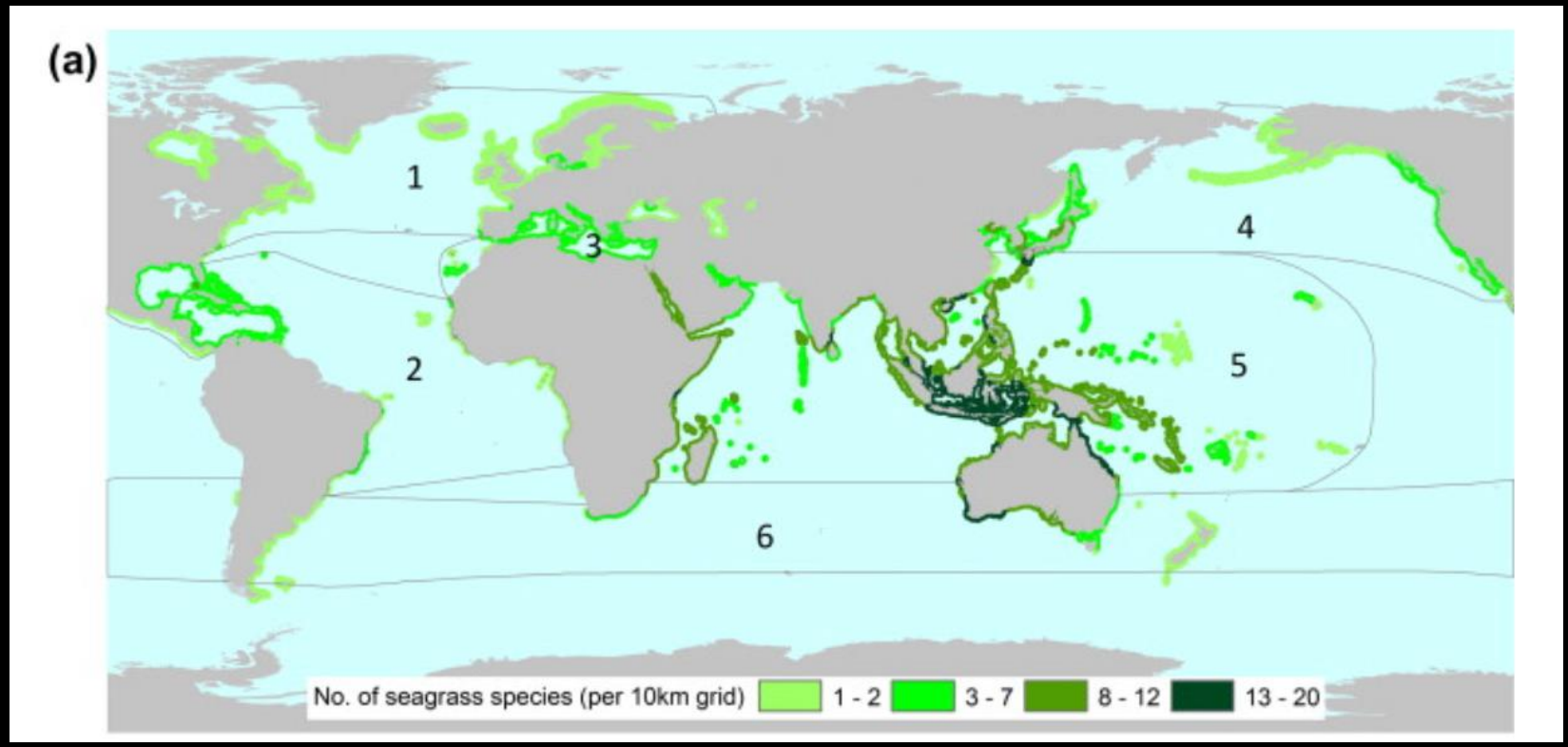
Seagrasses are not algae or seaweed.

What is seagrass?

- Found on the coastlines of every ocean save the Antarctic
- ~ 59 species reported

Diversity is usually low (1- 5 species per region), hotspots in the indo-pacific.

- Australia 29 species
- Japan 16 species
- India 14 species



Short et al. 2011

What is seagrass?

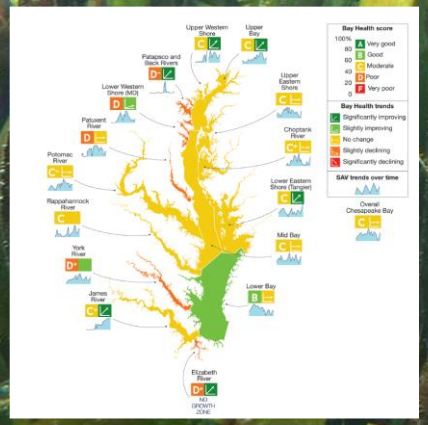
These plants can form vast underwater meadows, functioning as underwater prairies that provide a wide suite of ecosystem services.

Why do we care?

. . . it provides habitat for fish, crabs, and benthos (primary structure in shallow water).

. . . waterfowl eat the plants and seeds.

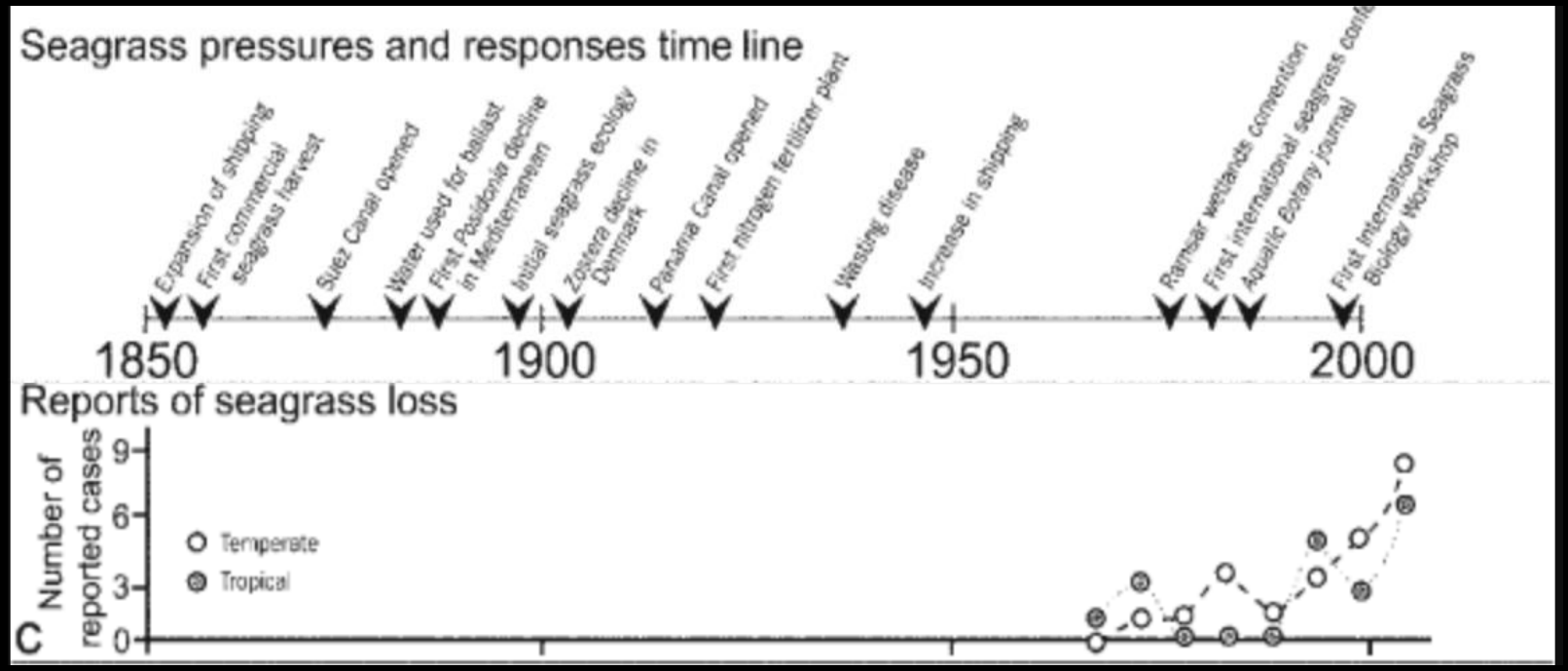
. . . it improves water clarity.
It *takes up nutrients*.
Its roots *anchor sediment*.
Its leaves *slow water movement*.



. . . it is a great indicator of ecosystem health.
SAV area is one of the main measures used to judge progress in restoring Chesapeake Bay.

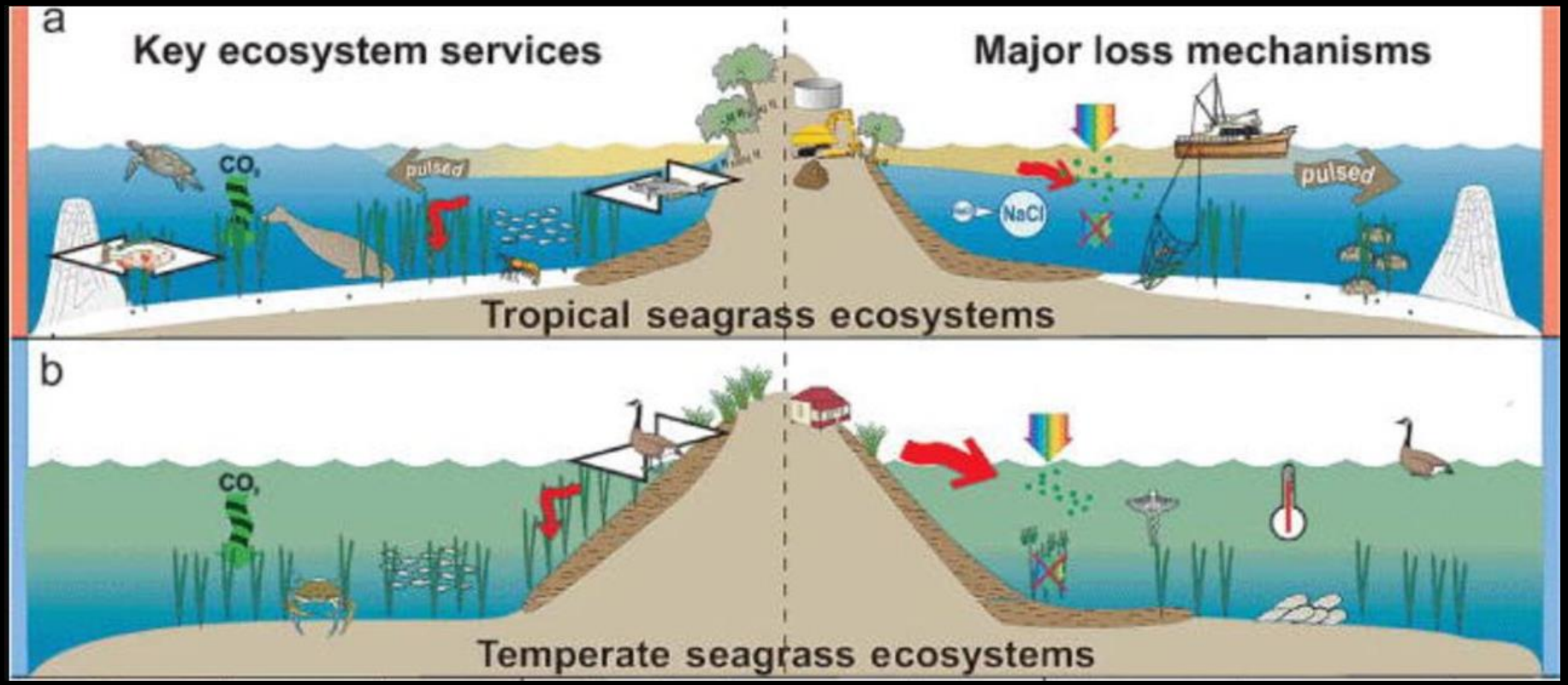
…and it sequesters carbon.

A global crisis for seagrass ecosystems



Orth et al. 2006

A global crisis for seagrass ecosystems



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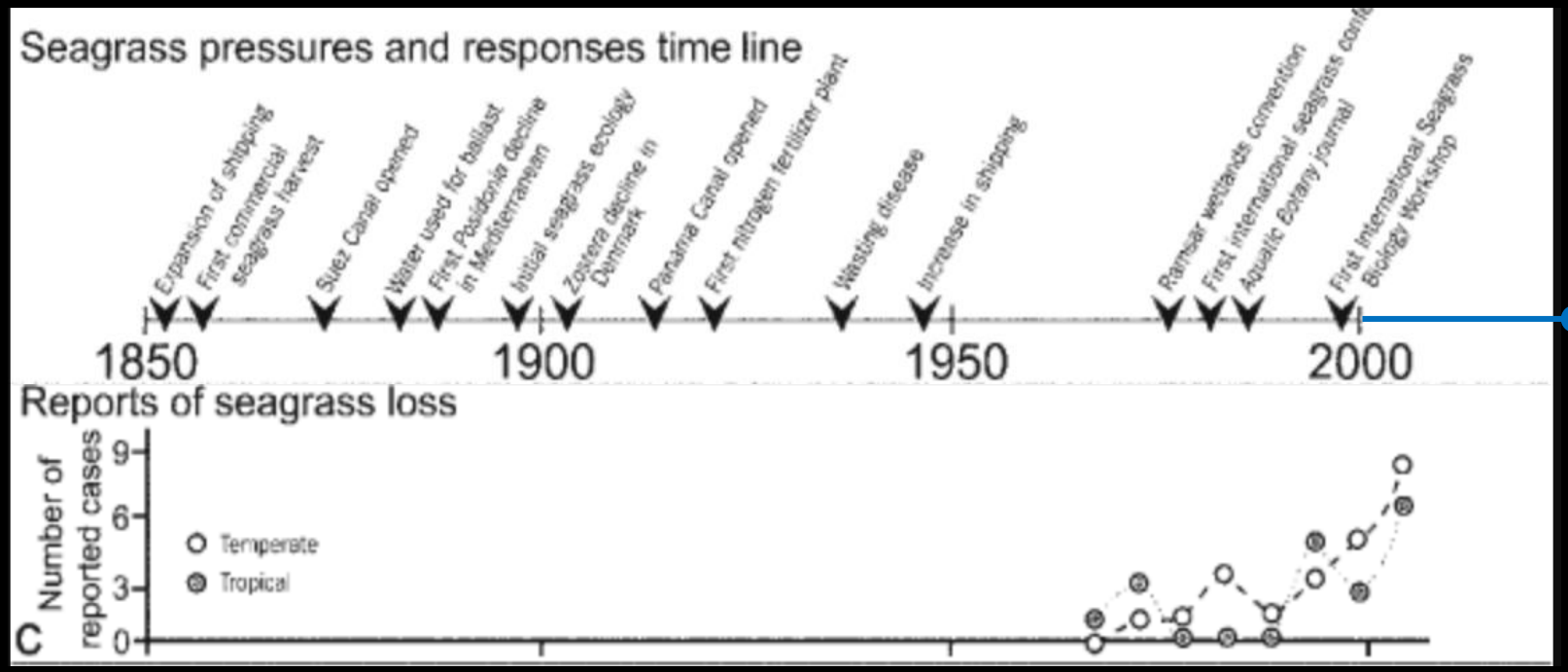
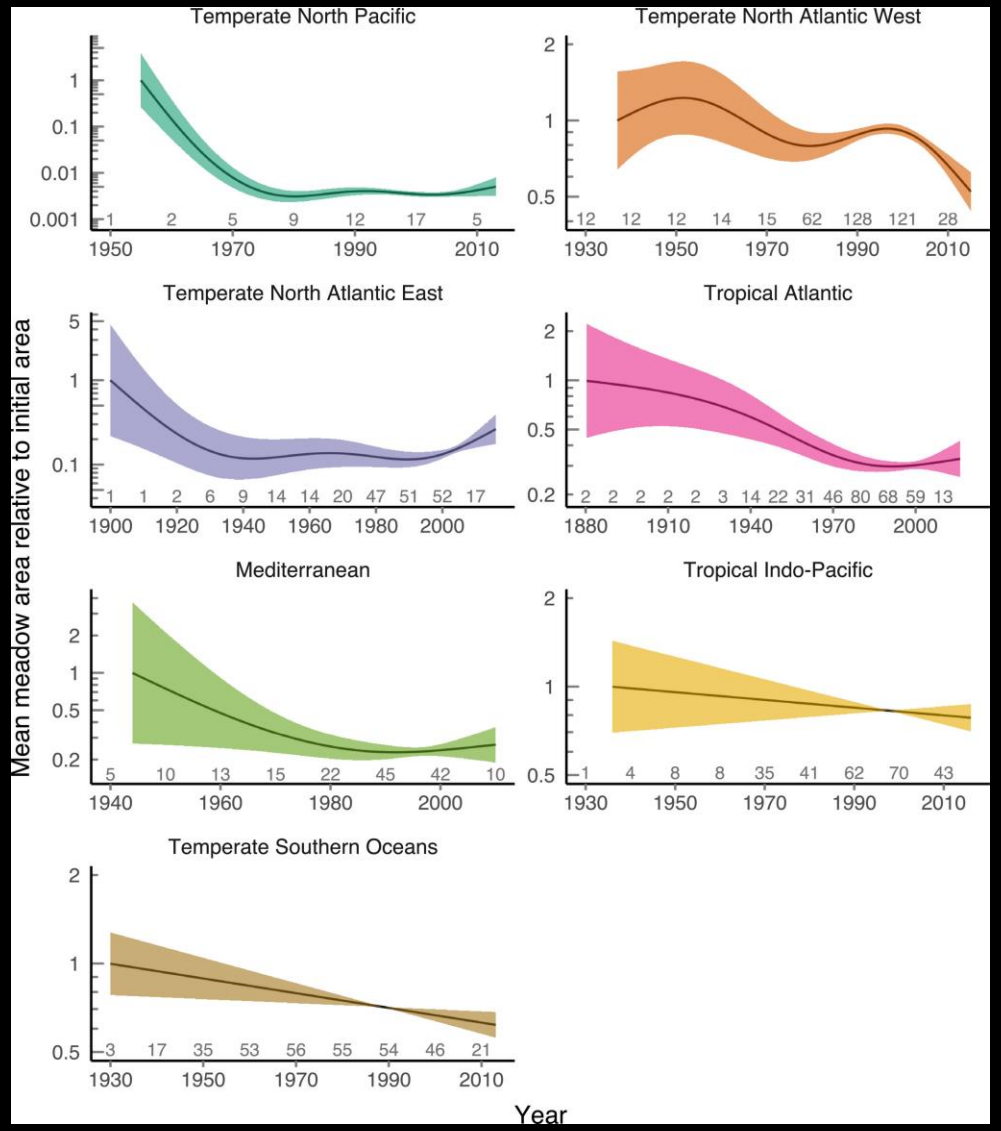


We are here

Orth et al. 2006

A global crisis for seagrass ecosystems

The Status Today



Dunic et al. 2021

- Bad news:
  - Ongoing declines in some regions
- Good news:
  - Declines in many areas have leveled out
  - Seeing some signs of recovery
- The Big Unknowns:
  - How much seagrass is out there?
  - How will climate change affect the conservation and recovery of seagrass ecosystems?

The SAV of Virginia

Freshwater grasses

Seagrasses

Seagrass of Virginia

Seagrasses

Eelgrass
Zostera marina

Widgeongrass
Ruppia maritima

Primary Threats Facing Virginia Seagrass over the past 100 years:

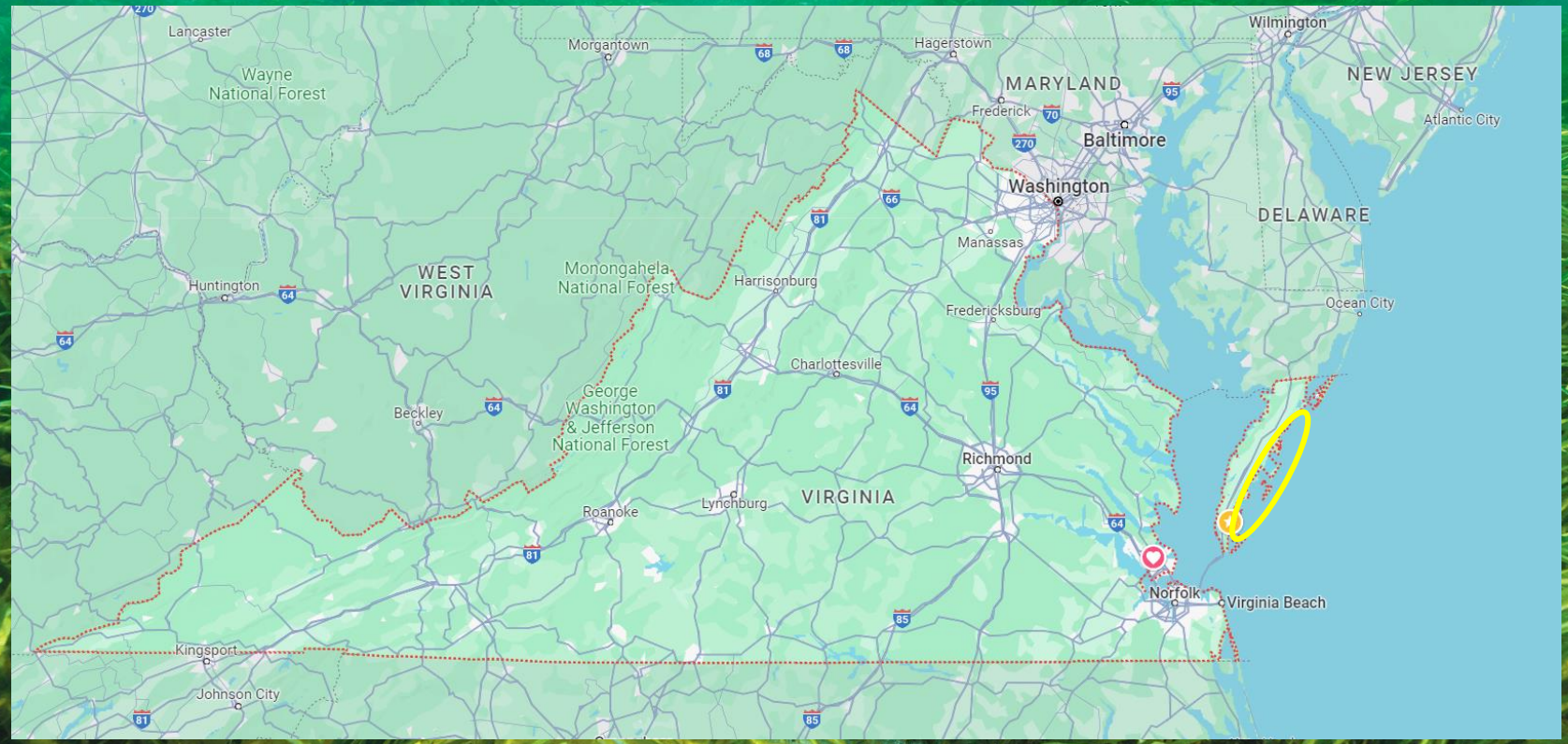
- Eelgrass Wasting Disease (1930's, today?)

- Water Quality Issues (1950's to present)

- Warming Waters / Climate Change (2000 to present)

Virginia Seaside - 1929

Virginia's Coastal Bays were home to expansive eelgrass meadows covering as much as 45,000 acres of bottom

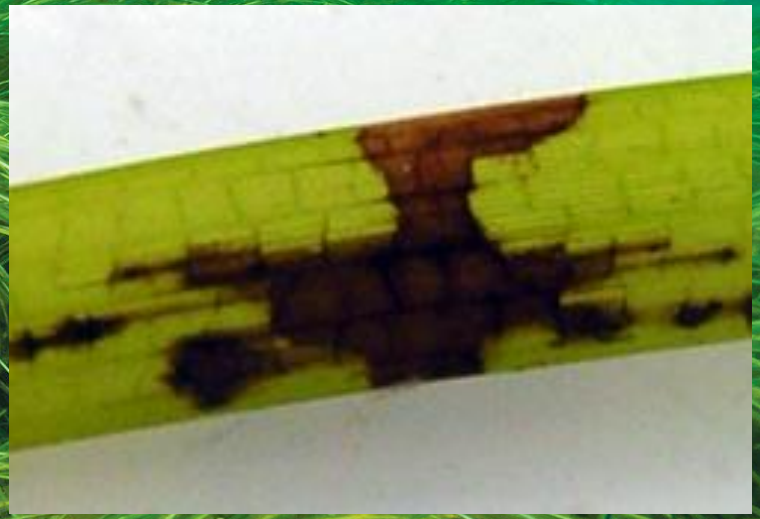


Virginia Seaside - 1929

There was a growing industry based around harvesting the bay scallops that lived in those meadows.

Virginia Seaside - 1930

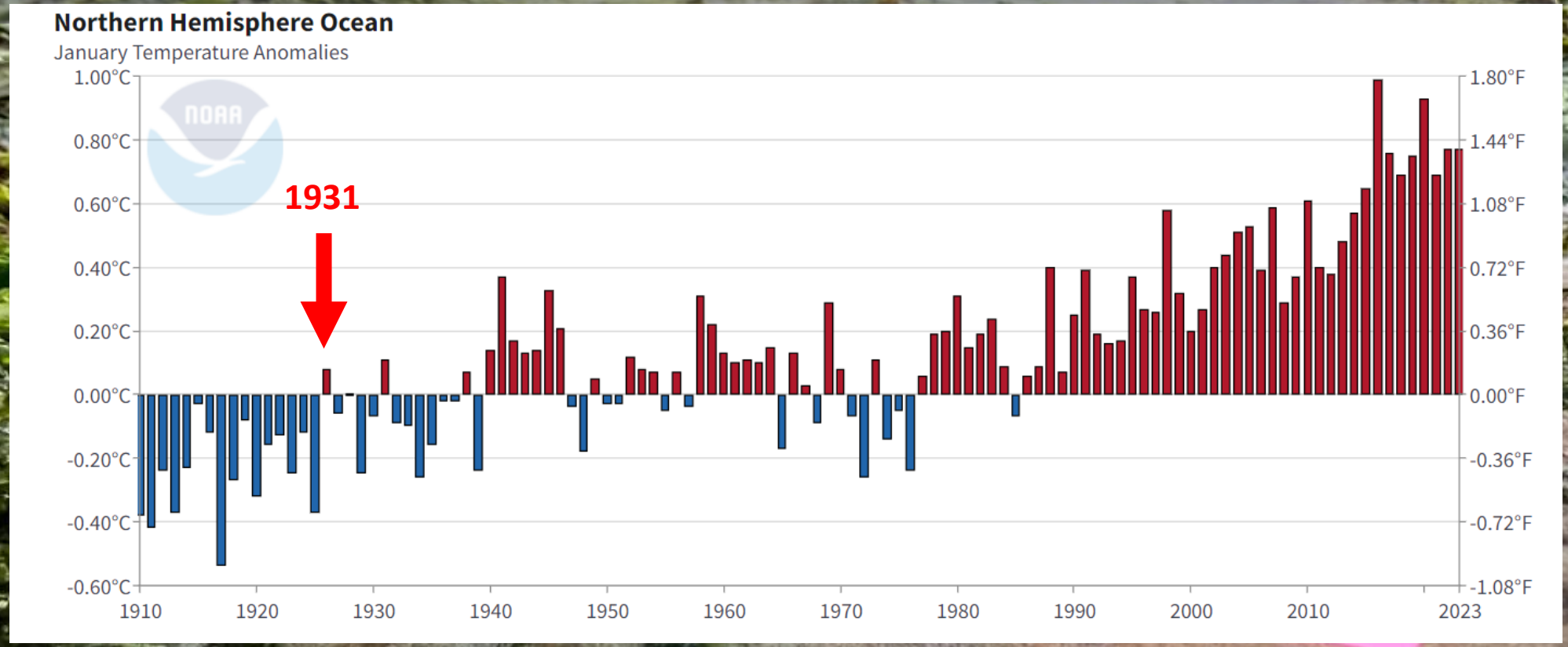
First reports in VA of black lesions on the seagrass. Lesions caused by a protist, *Labyrinthula zosterae*, (seagrass wasting disease)



Virginia Seaside - 1931

Set off by an unusually warm winter, the protist, *Labyrinthula zosterae*, (seagrass wasting disease) erupts throughout the Atlantic Basin

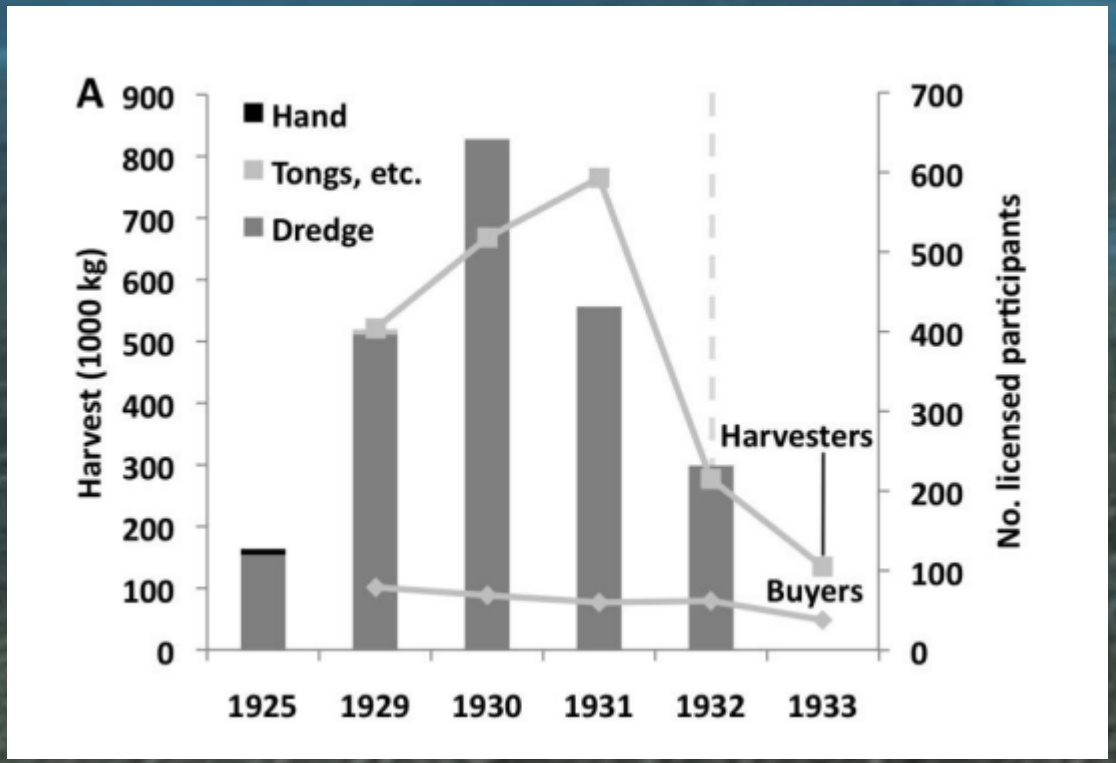
By the end of the summer of 1931, 90% of eelgrass in the Atlantic was gone



Virginia Seaside - 1932

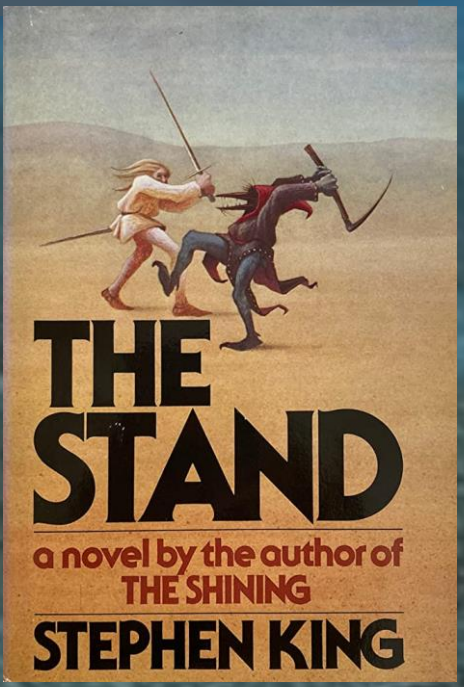
By the end of the summer of 1932, > 99% of eelgrass in the Atlantic was gone.

In VA, the scallop harvesters could find no meadows to work for scallops, harvesting over bare sediment. This was the last summer there as a scallop harvest in VA.

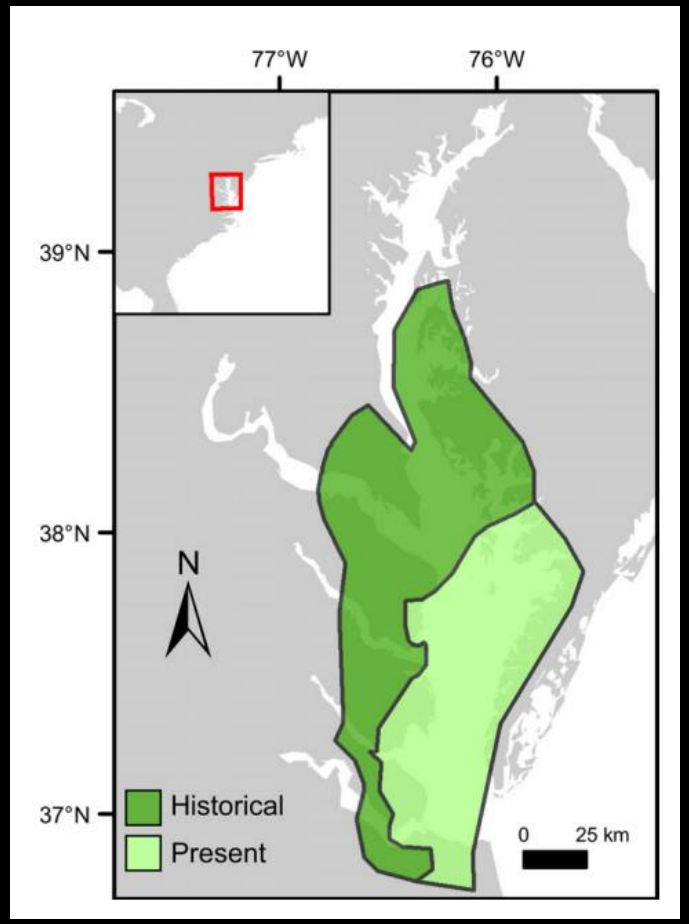


Oreska et al. 2017

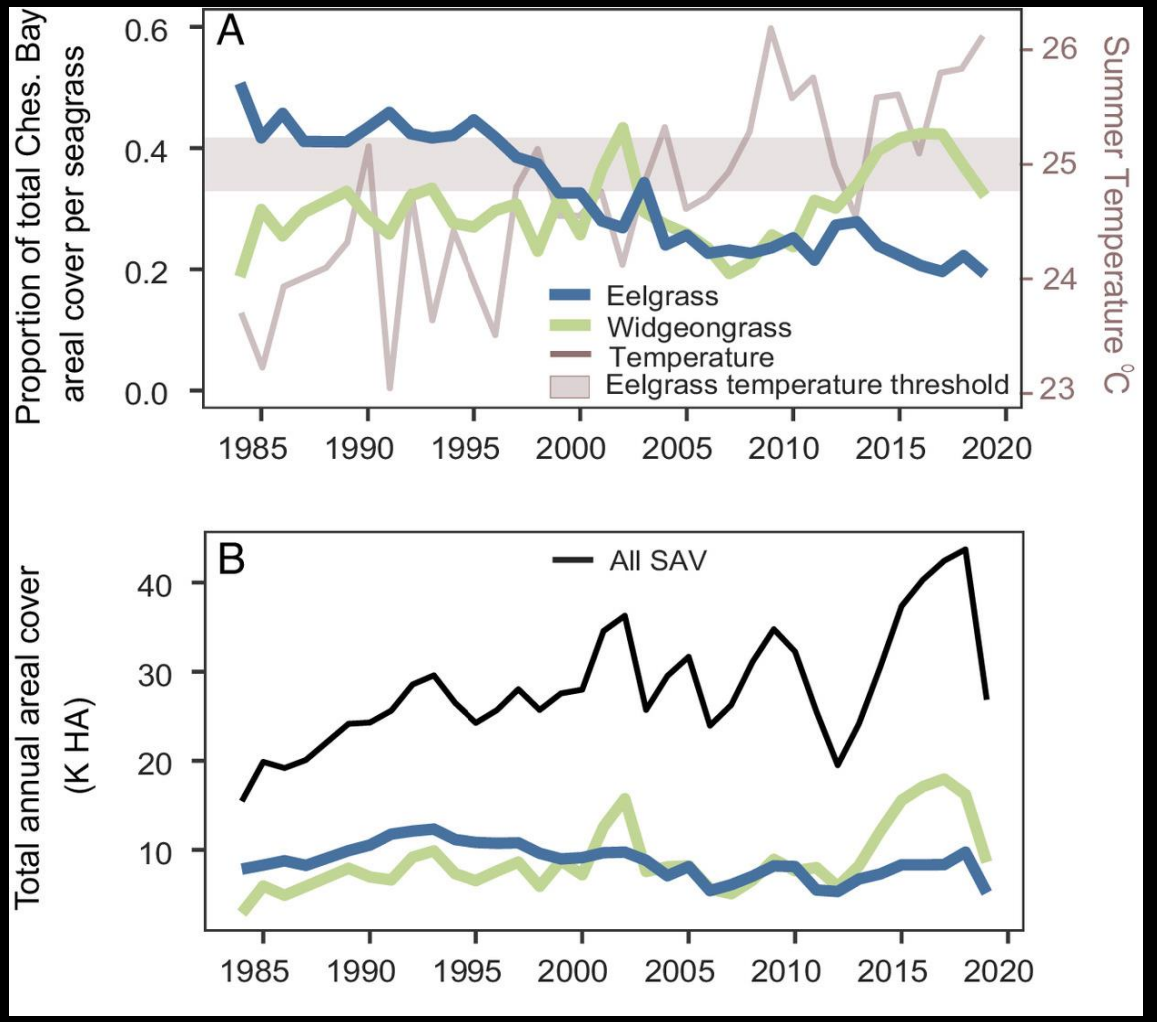
Eelgrass associated fauna such as Brant and Bay Scallops declined. The Atlantic Eelgrass Limpet, went completely extinct.



Chesapeake Bay



Unlike the VA Coastal Lagoons, eelgrass in the Chesapeake recovered quickly (freshwater refuge populations), but water quality became an issue.



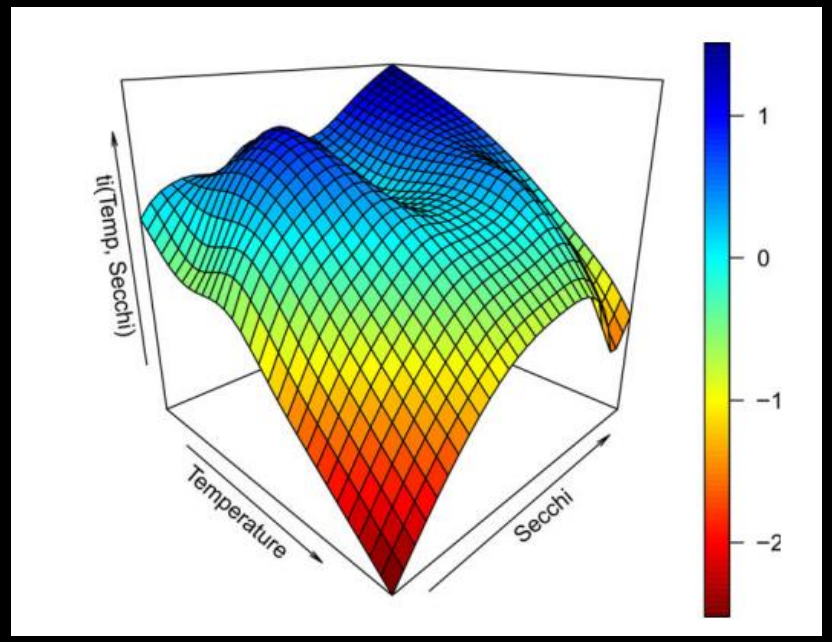
Hensel et al. 2023

Increasing Summer Temperatures are to blame

From 1984 to the early 1990's, eelgrass was on the way up

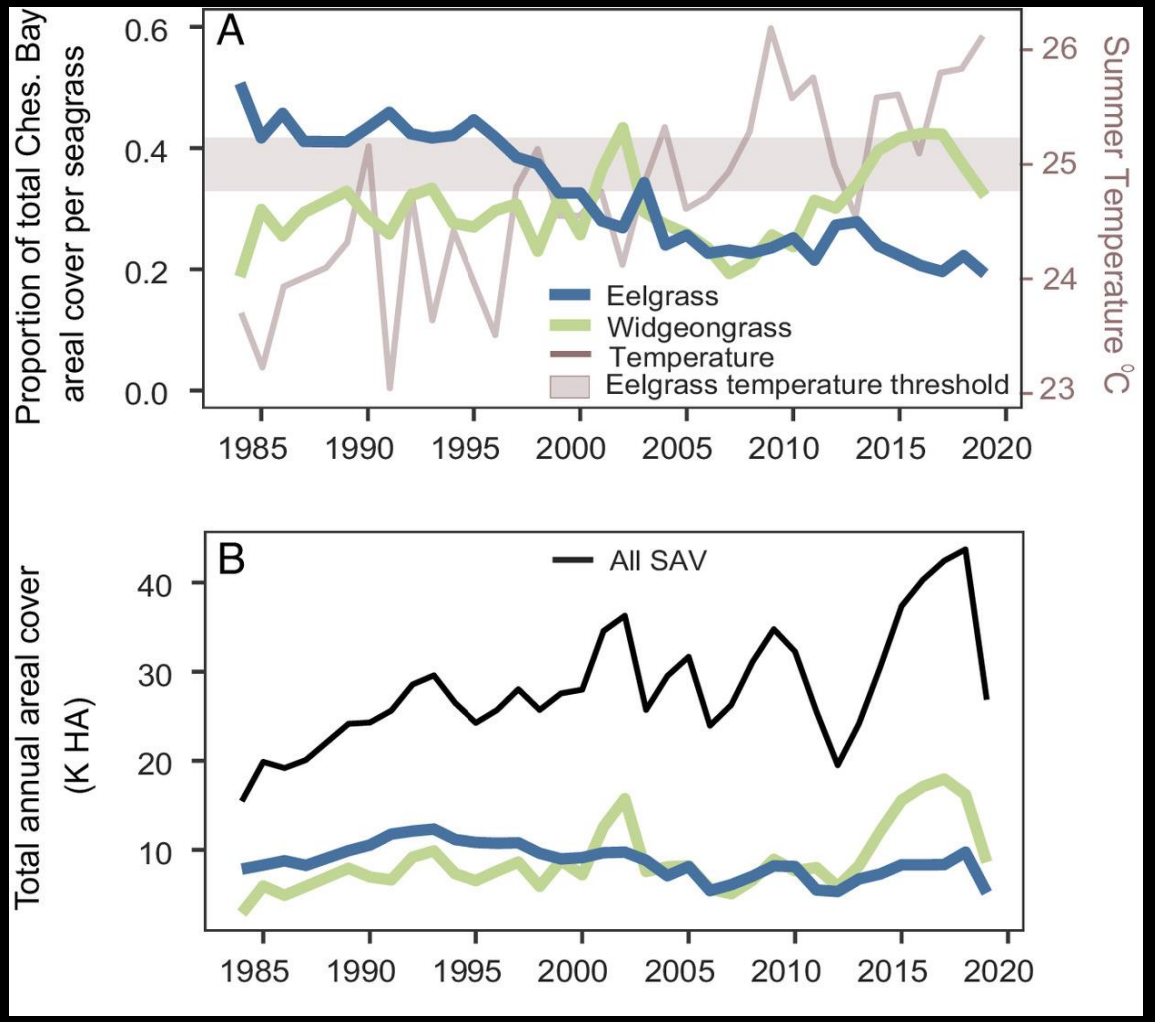
Since then, it has been in persistent steady decline

Chesapeake Bay



Lefcheck et al. 2017

The combination of poor water clarity and high temperatures are a death sentence for eelgrass, a northern temperate species



Hensel et al. 2023

Increasing Summer Temperatures are to blame

From 1984 to the early 1990's, eelgrass was on the way up

Since then, it has been in persistent steady decline

What can we do about it?

1) We can work to enhance water quality and light to support seagrass health!

2) In areas where conditions are appropriate for restoration, but the grass is absent, we can plant seagrasses.

3) In areas where there is a concern about future climate conditions:

i. Considering the potential for climate resilient seagrass species to be introduced from the south.
ii. Considering the potential to introduce more climate resilient genes into local populations.
iii. Considering the potential to enhance restoration success through use of climate resilient and locally present native species.

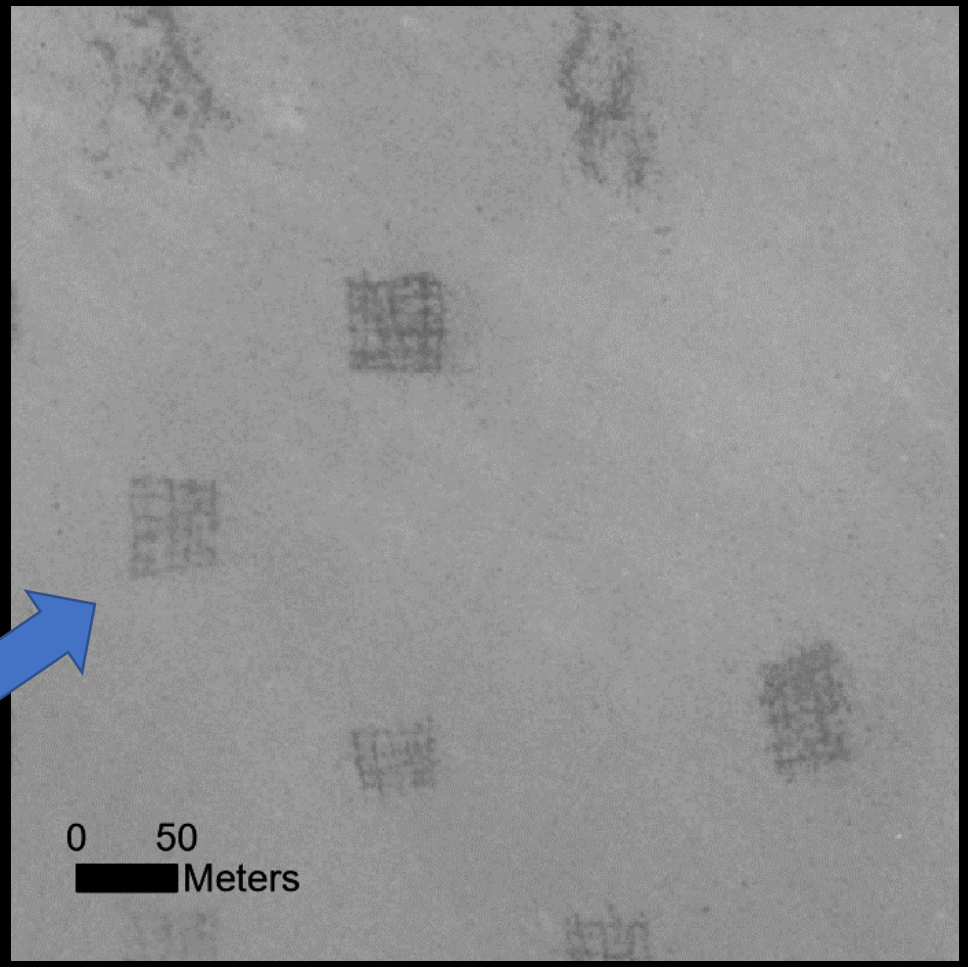
What can we do about it?

2) In areas where conditions are appropriate for restoration, but the grass is absent, we can plant seagrasses.

What we're doing about it

Restoration of VA's coastal lagoons

One acre plots
~100,000 seeds distributed per plot



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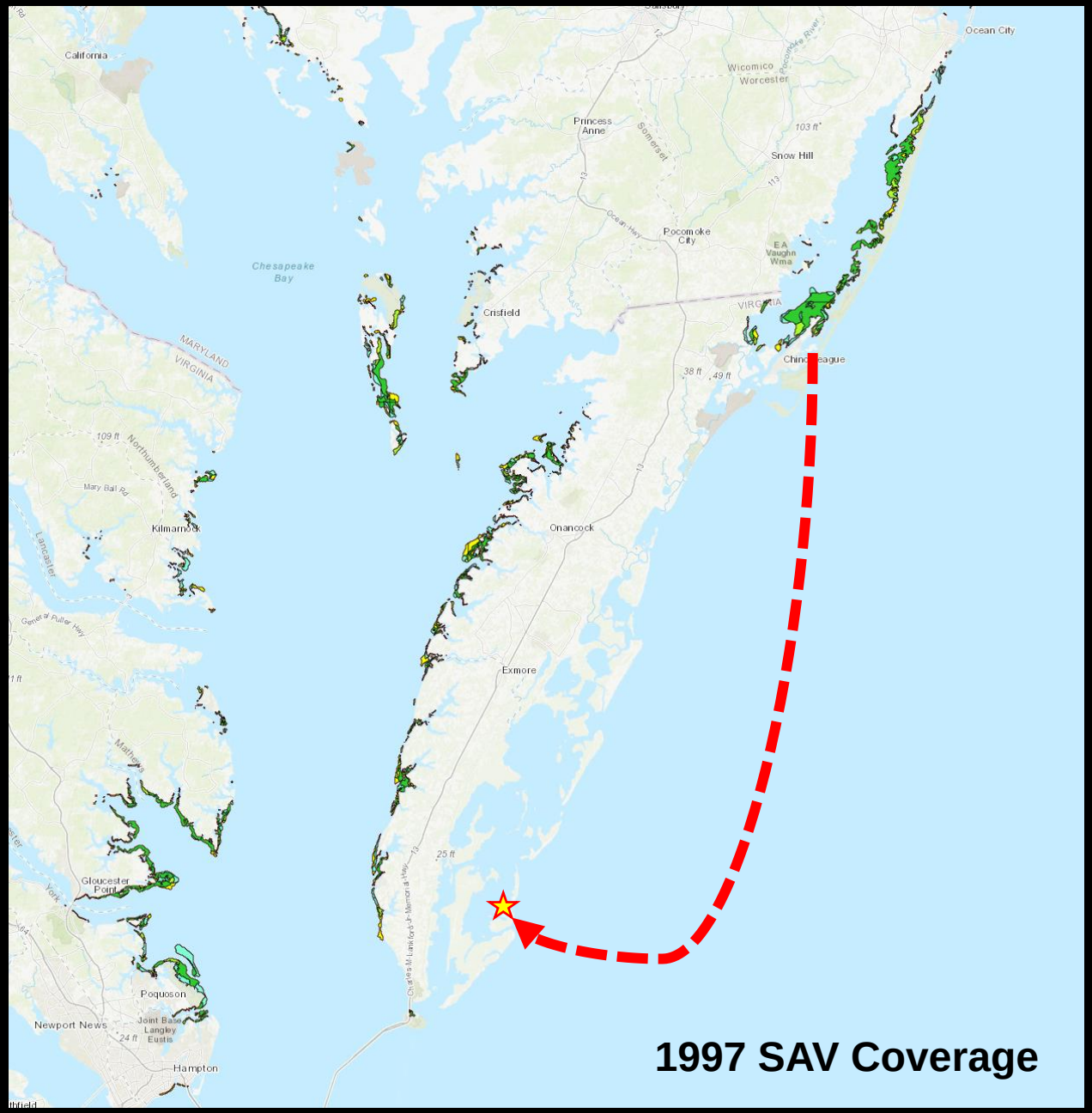


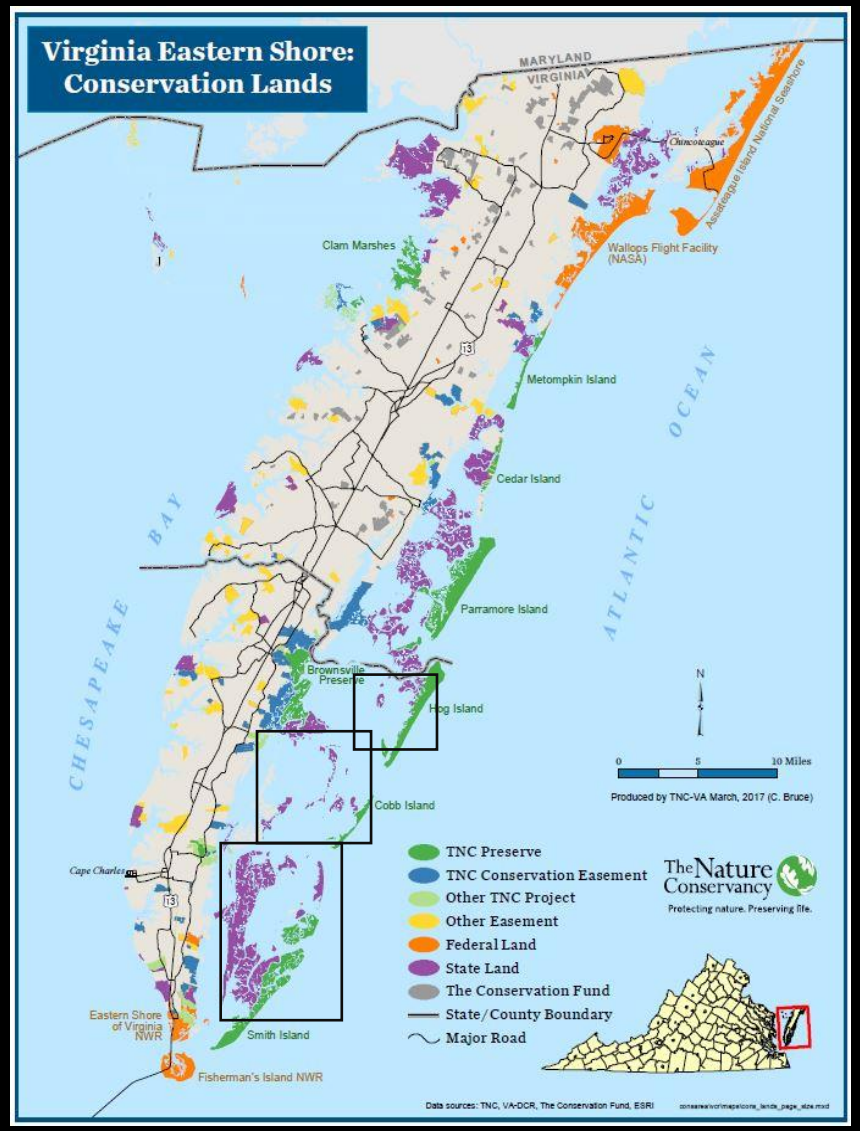
Eelgrass shoots were observed in small patches at the tip of wreck island in South Bay in 1997.

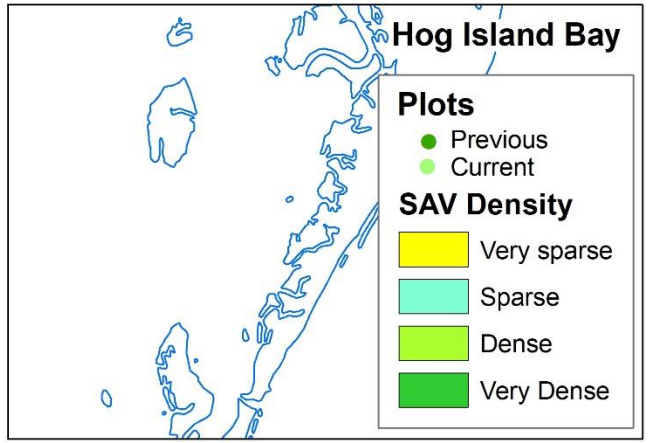
- First eelgrass in this bay since 1932

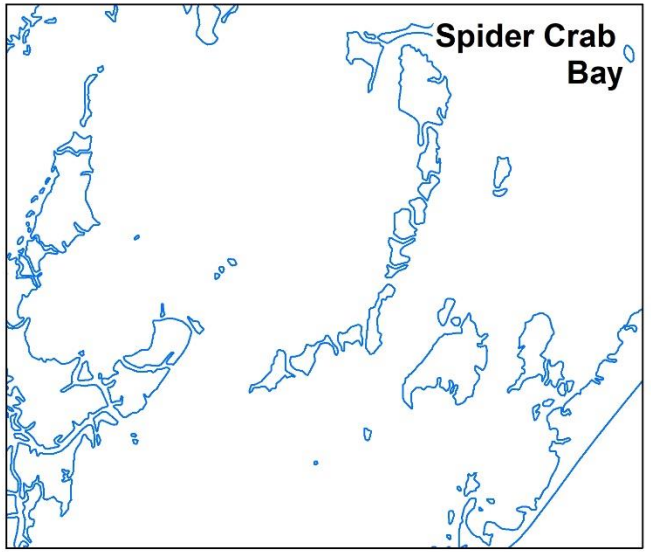
- Natural colonization (not restoration)

- Dispersal modeling suggests that source was most likely rafts of eelgrass from Chincoteague Bay to the north (Orth & Harwell 2002)

- Genetic analyses also support theory that recruits came from Chincoteague Bay (Reynolds et al. 2013)







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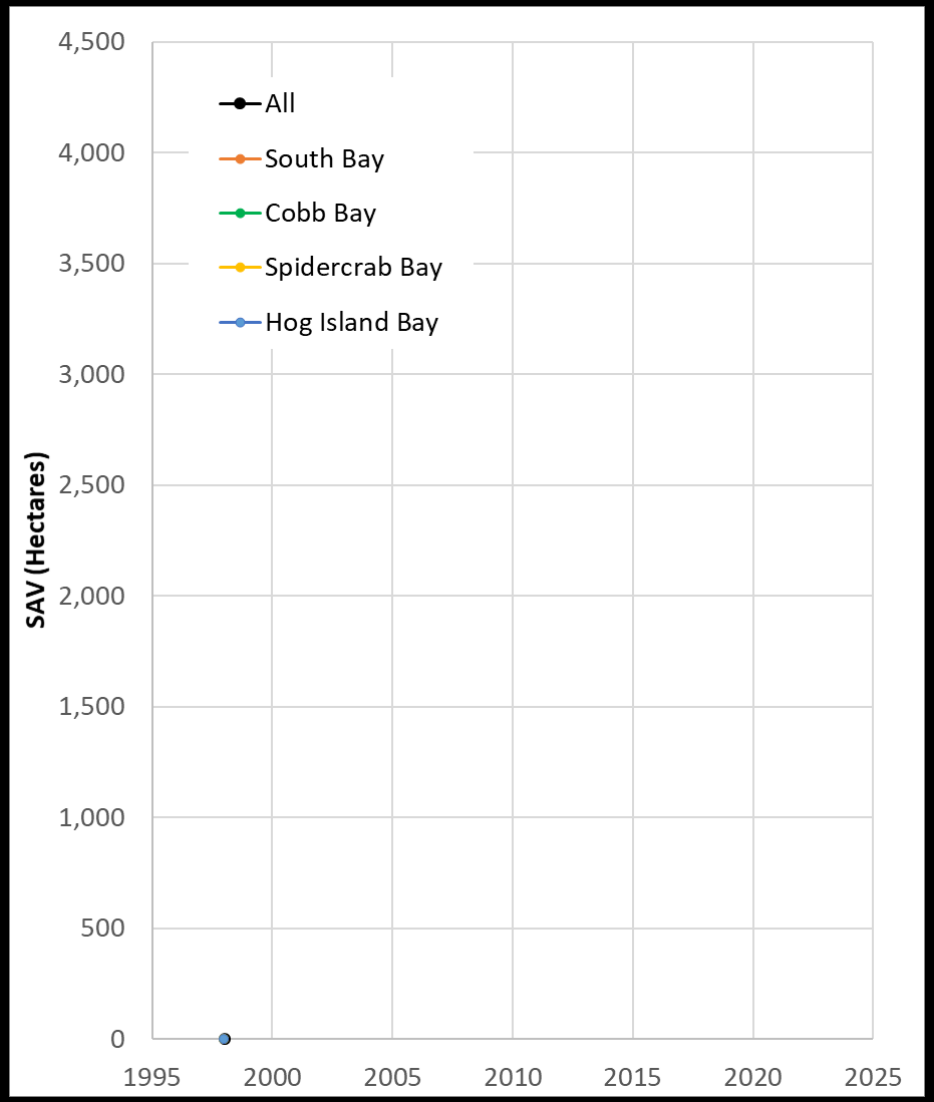

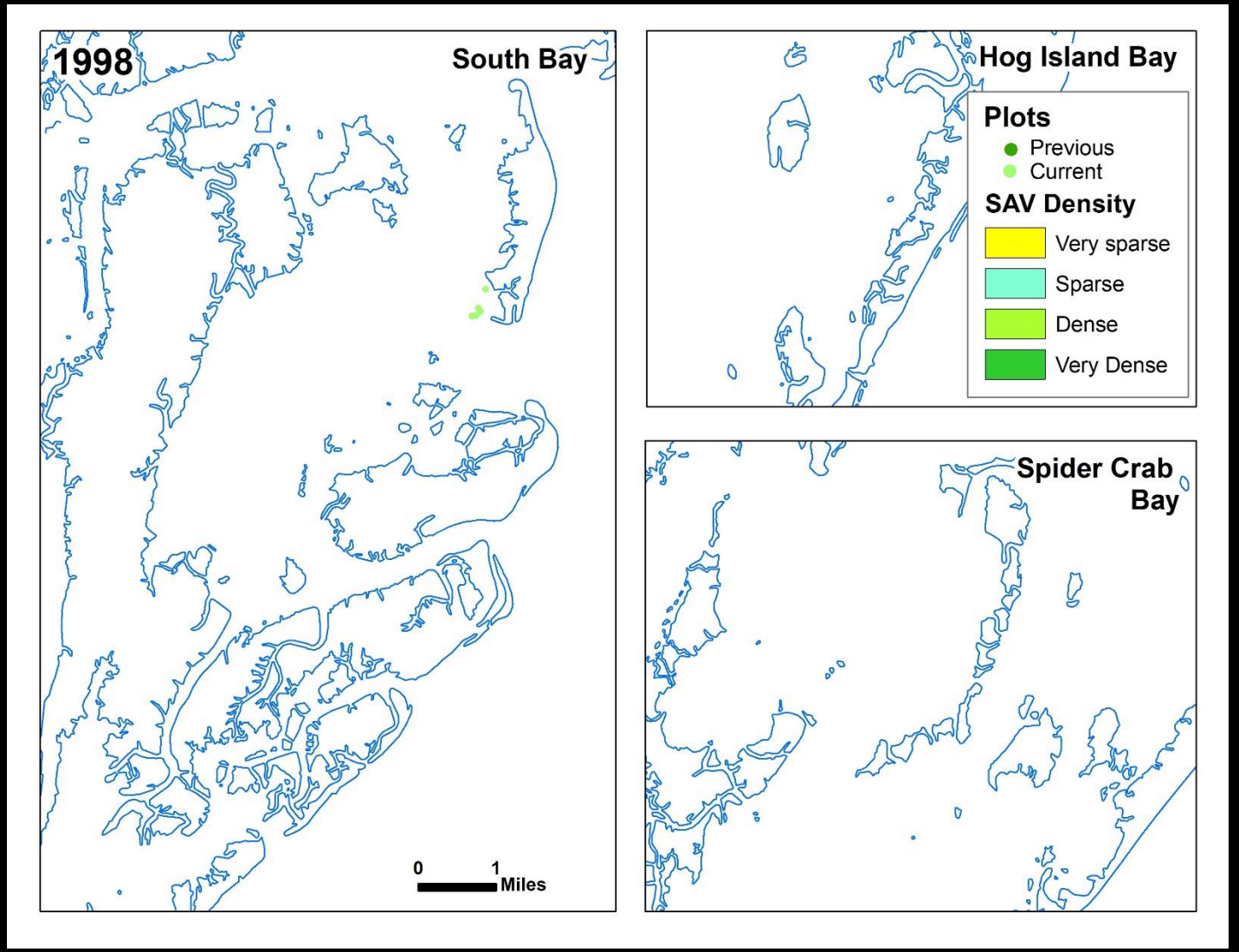

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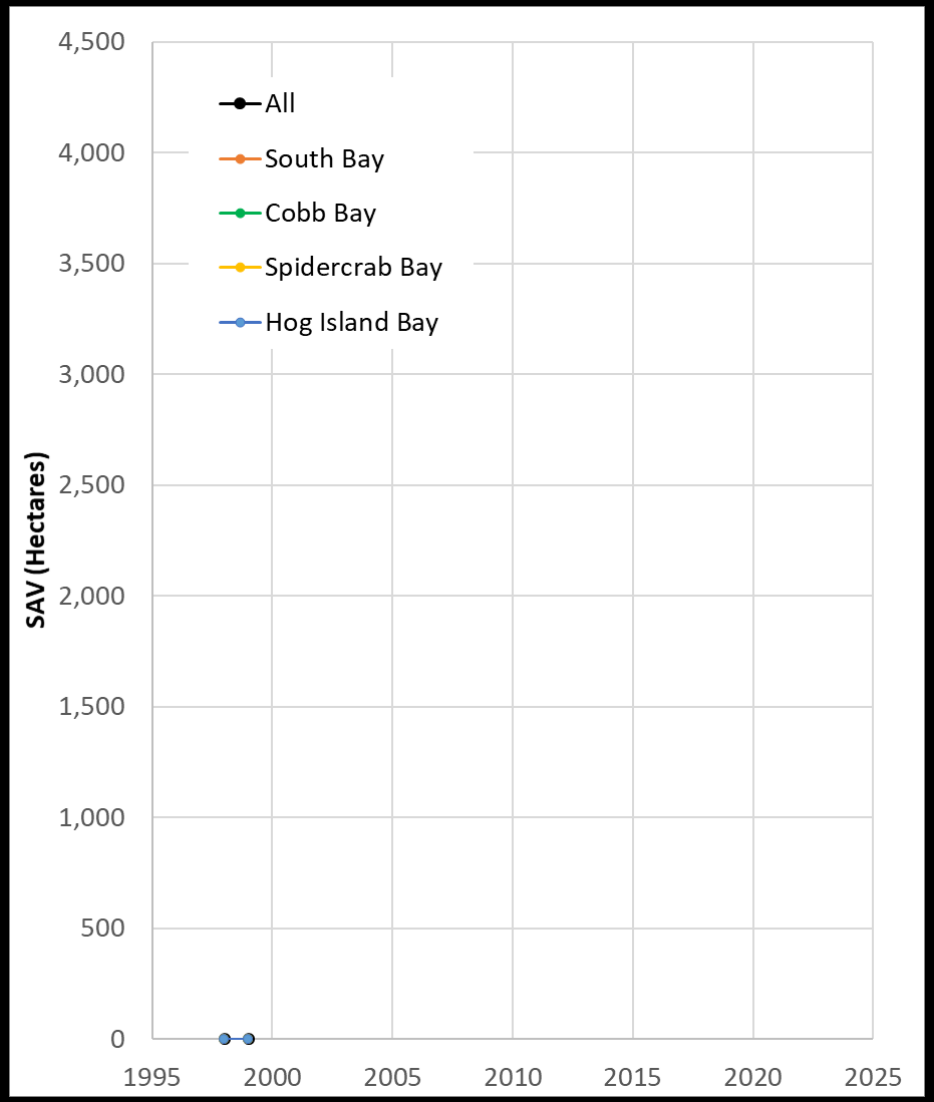

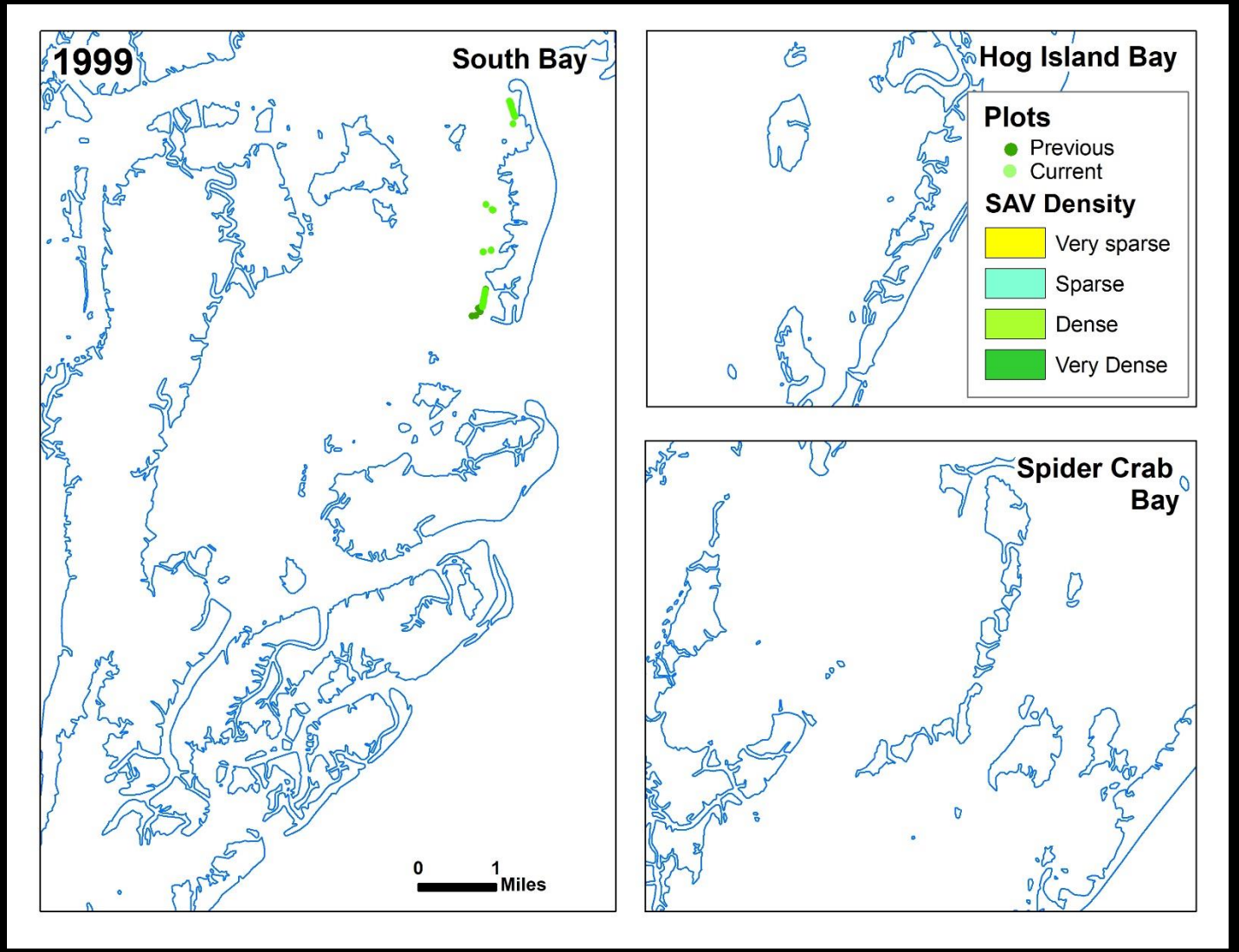

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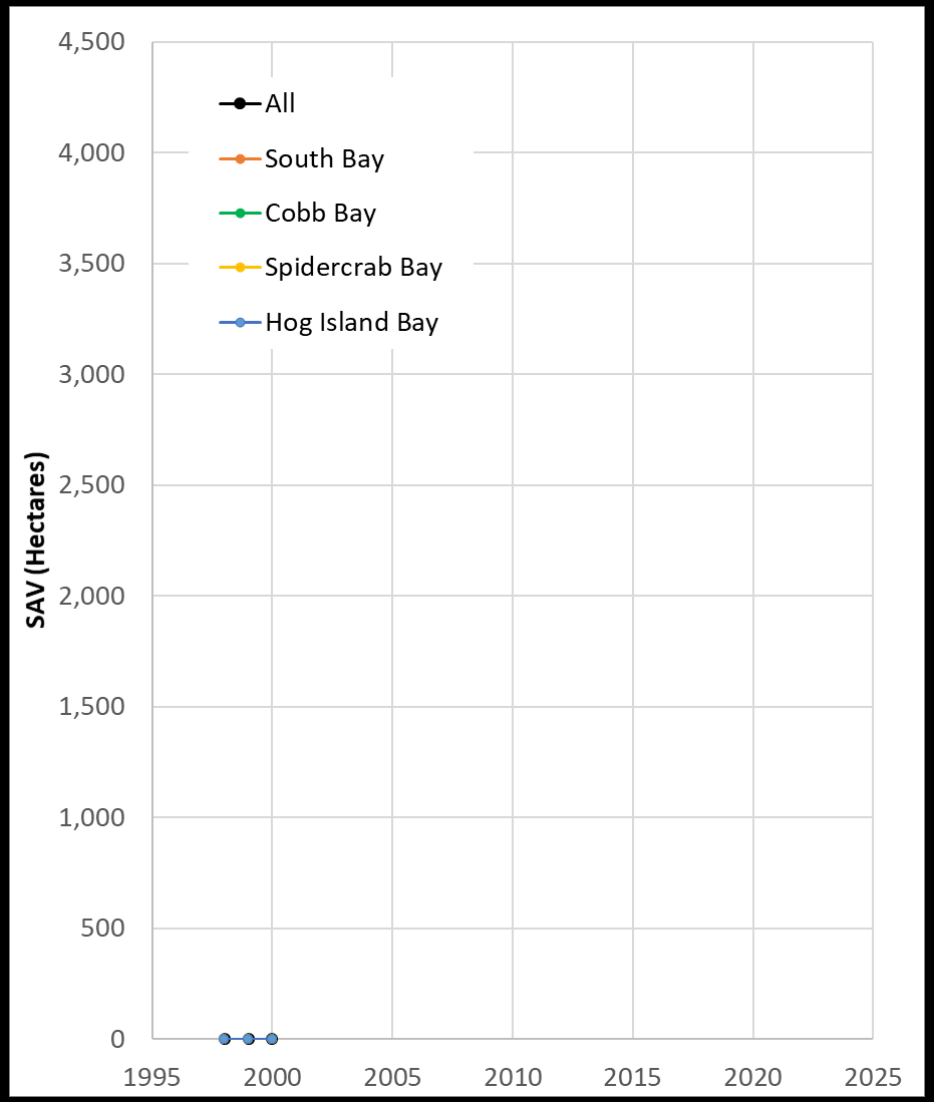

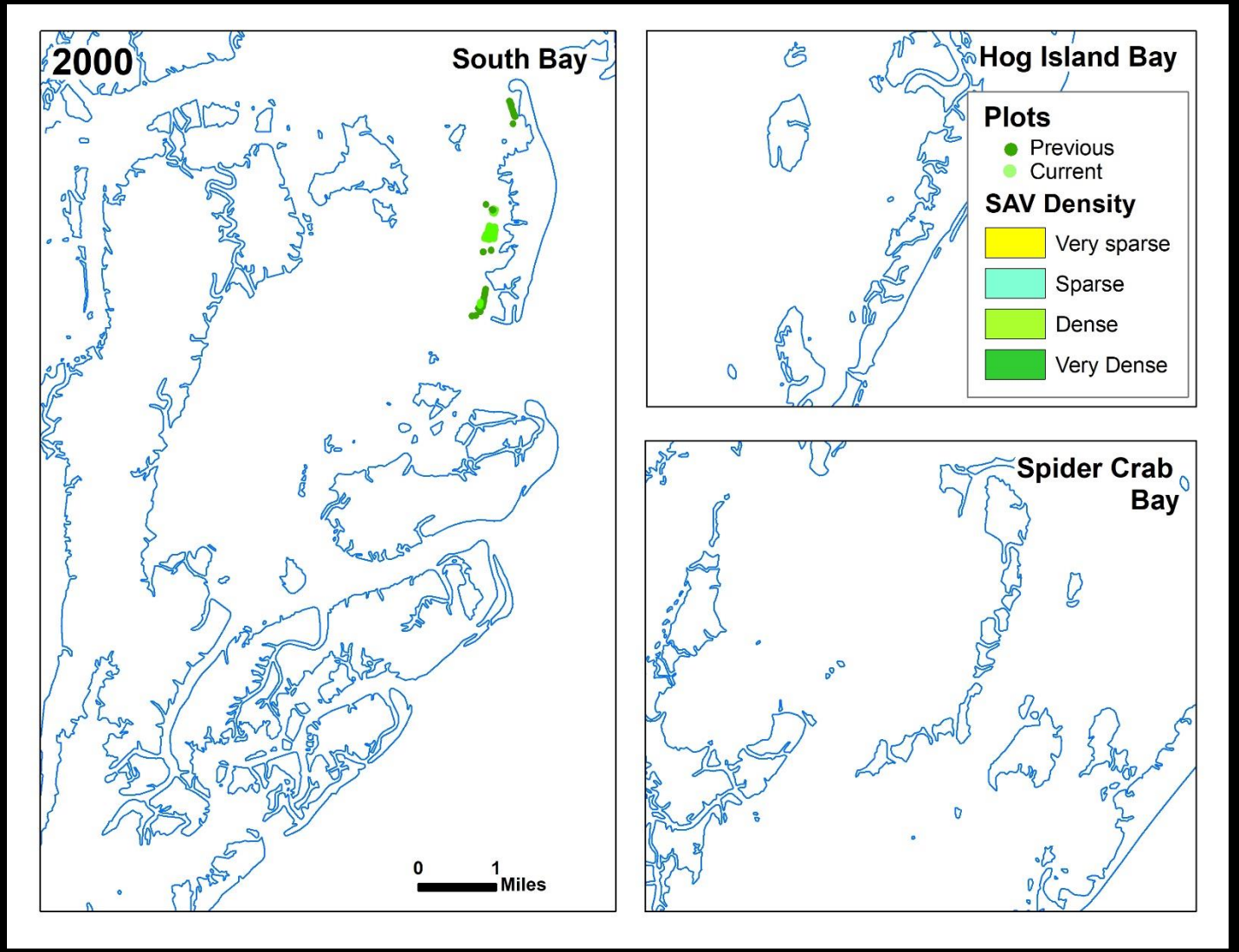

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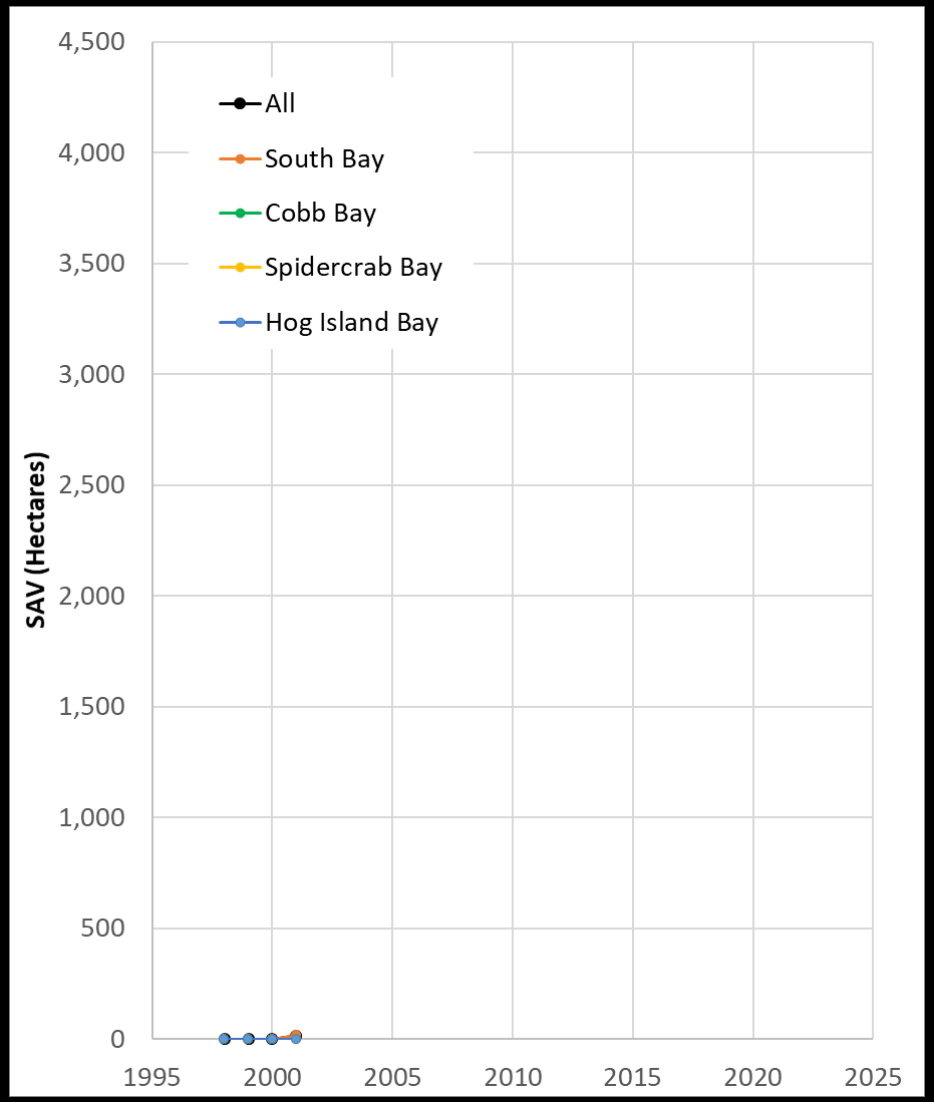

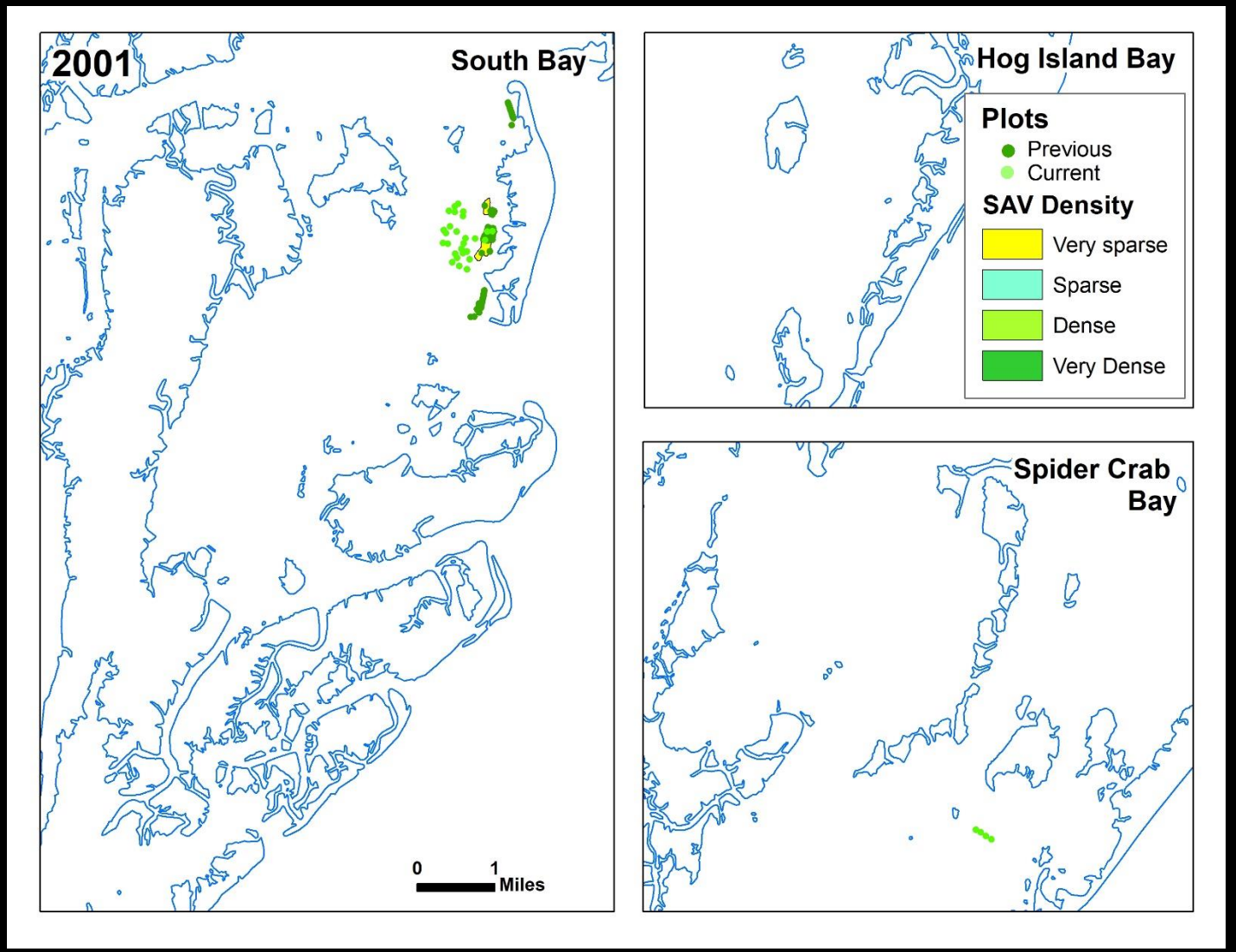

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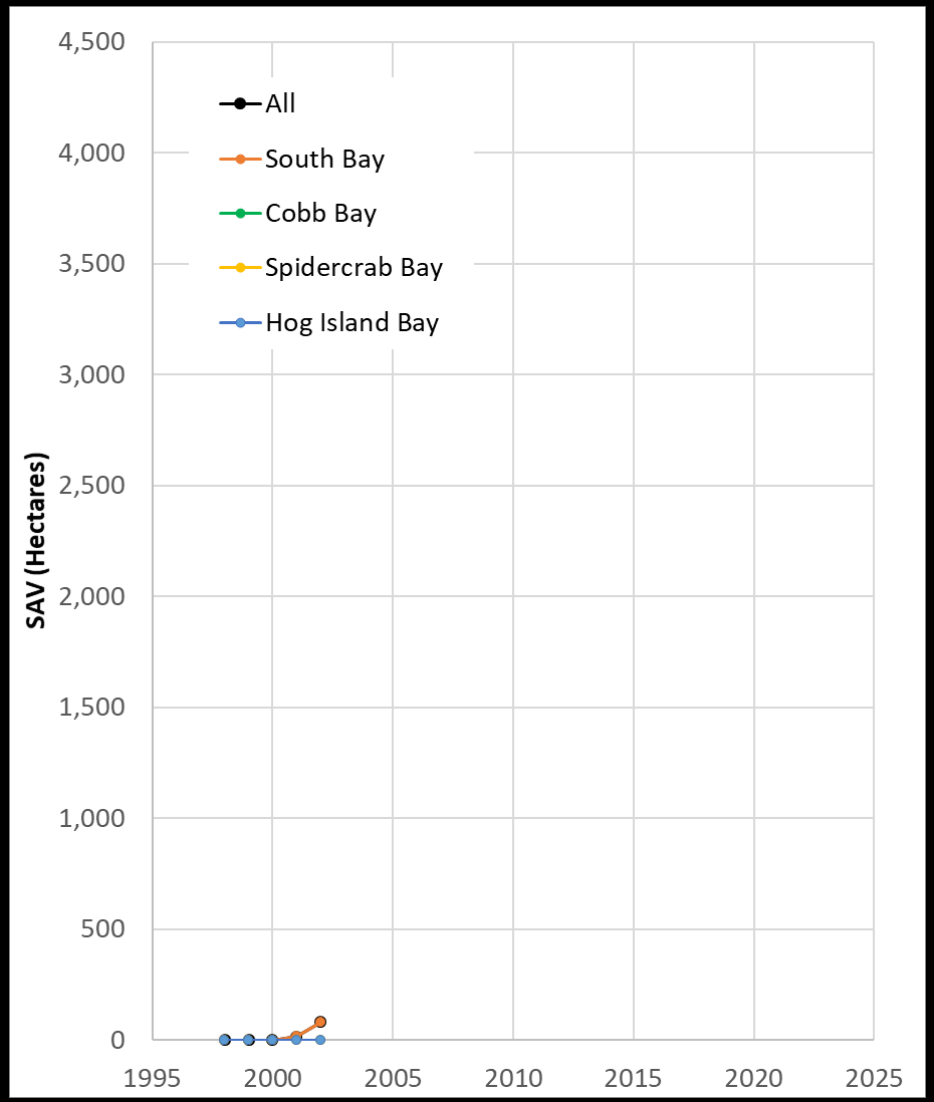

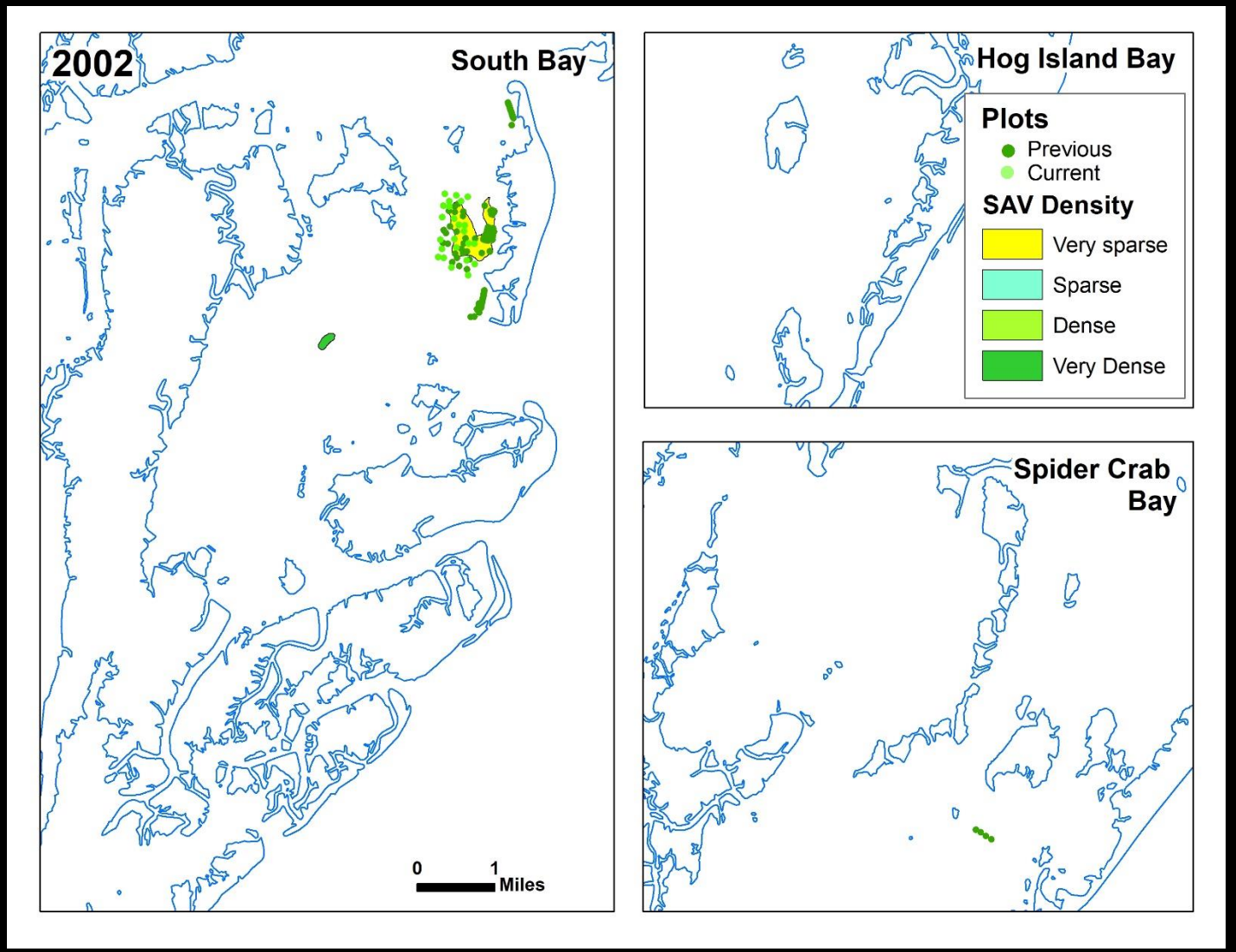

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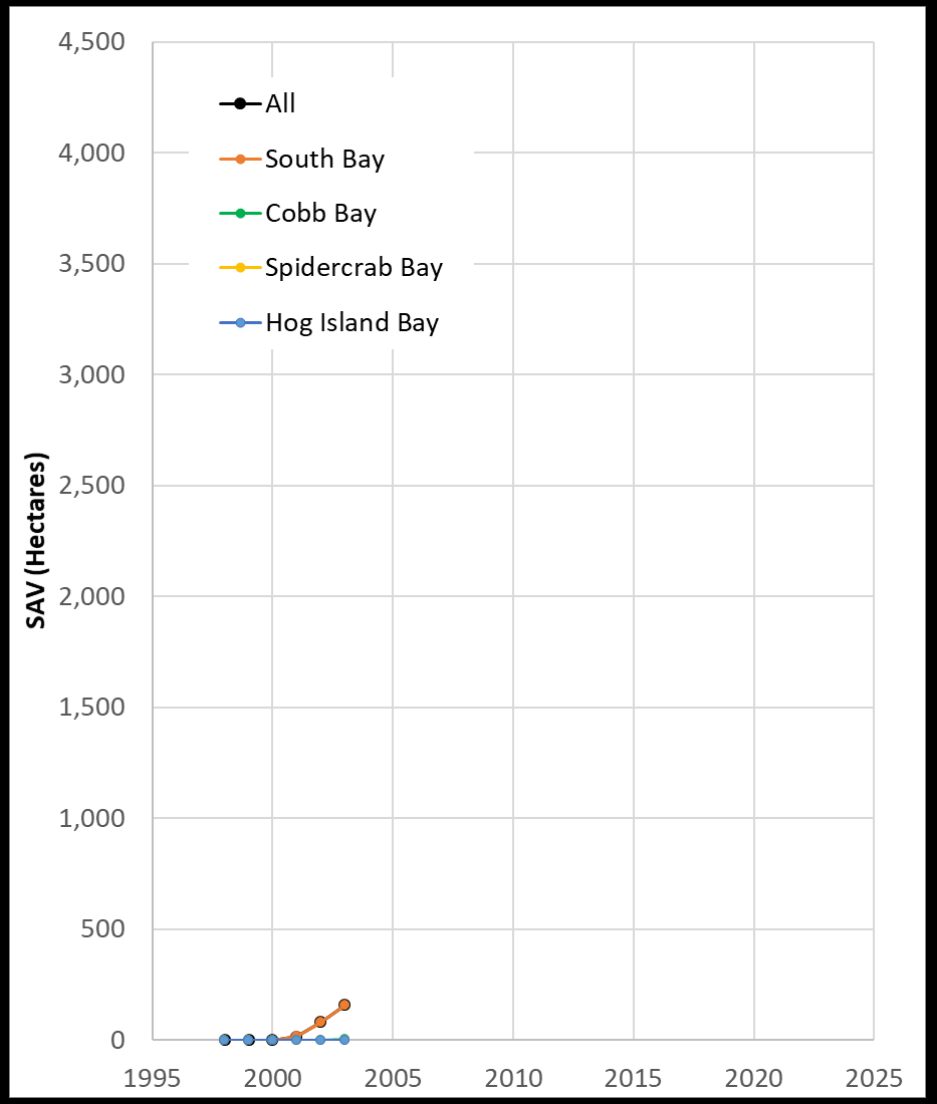

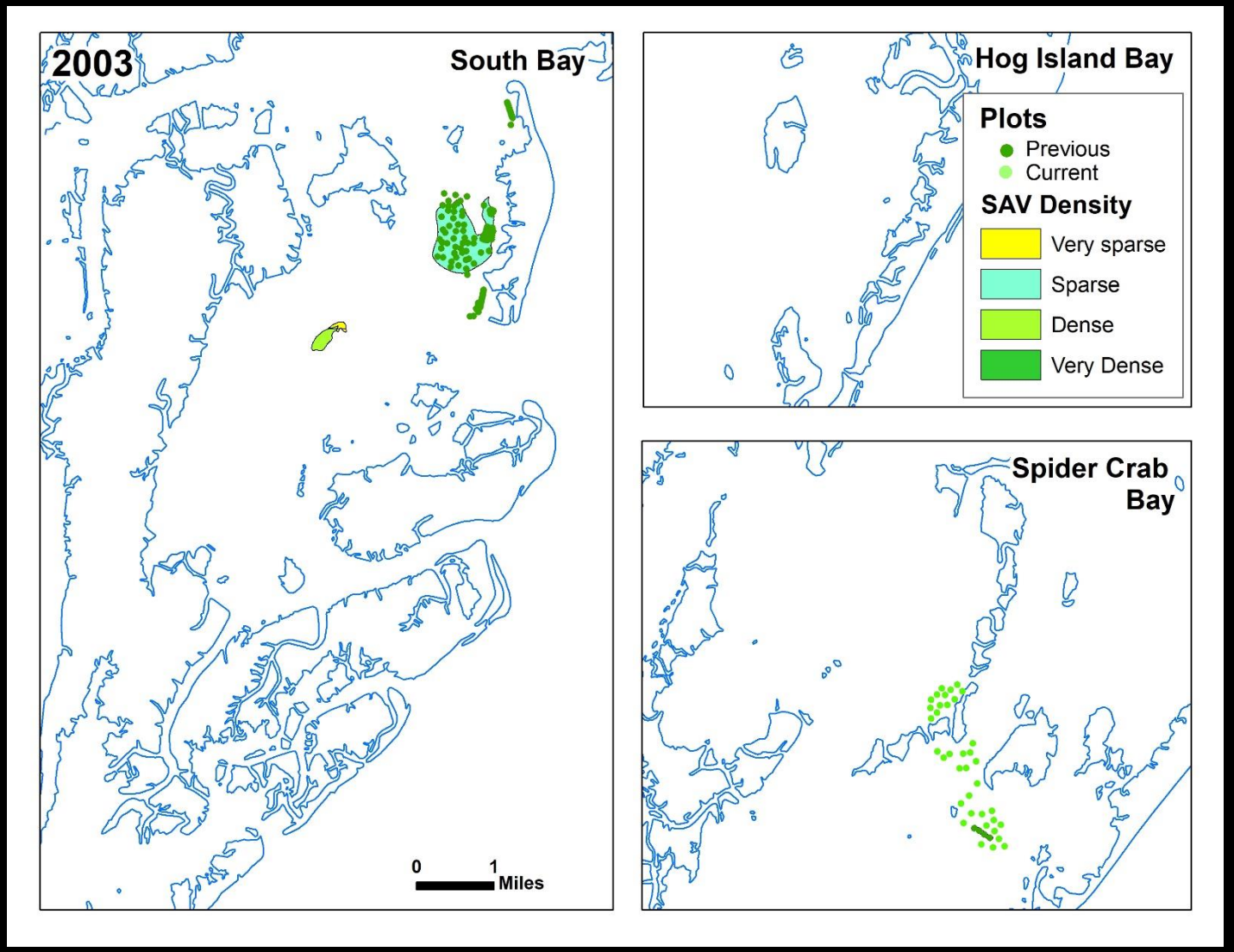

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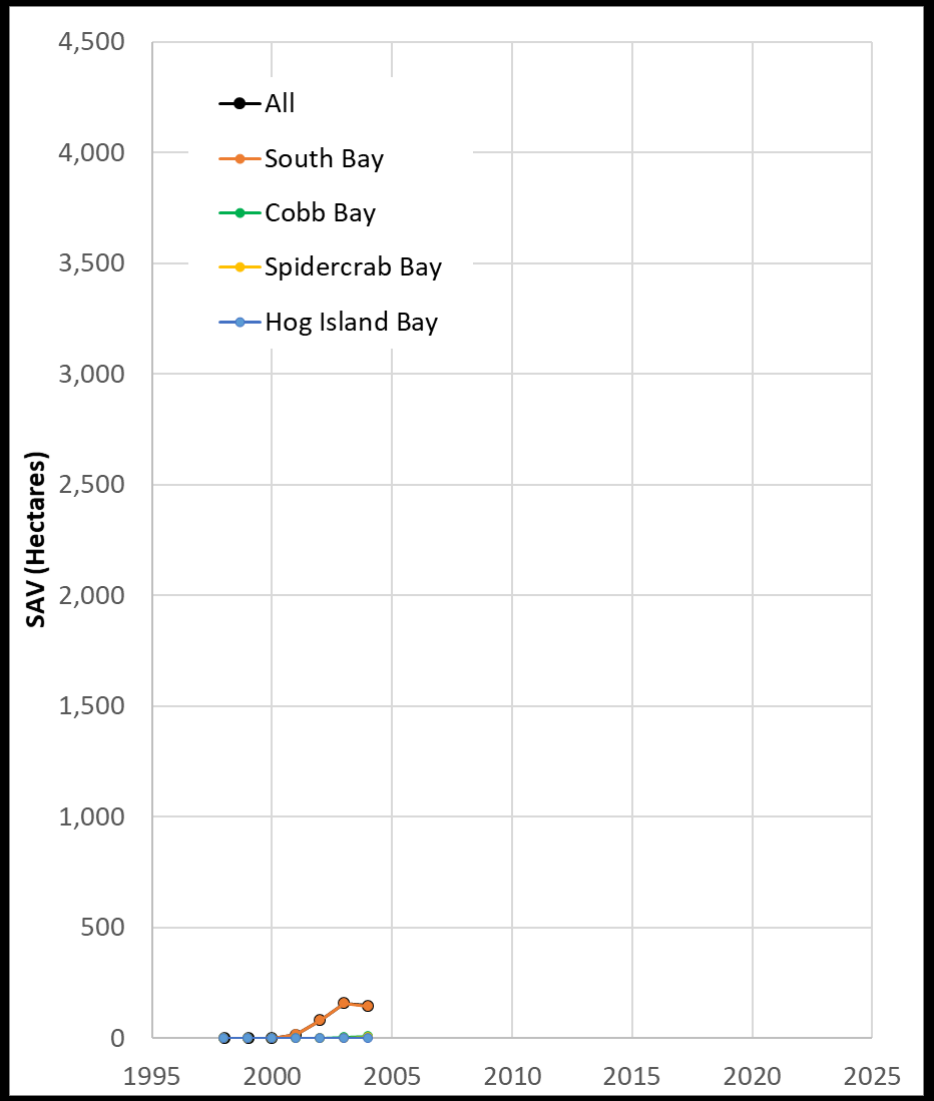

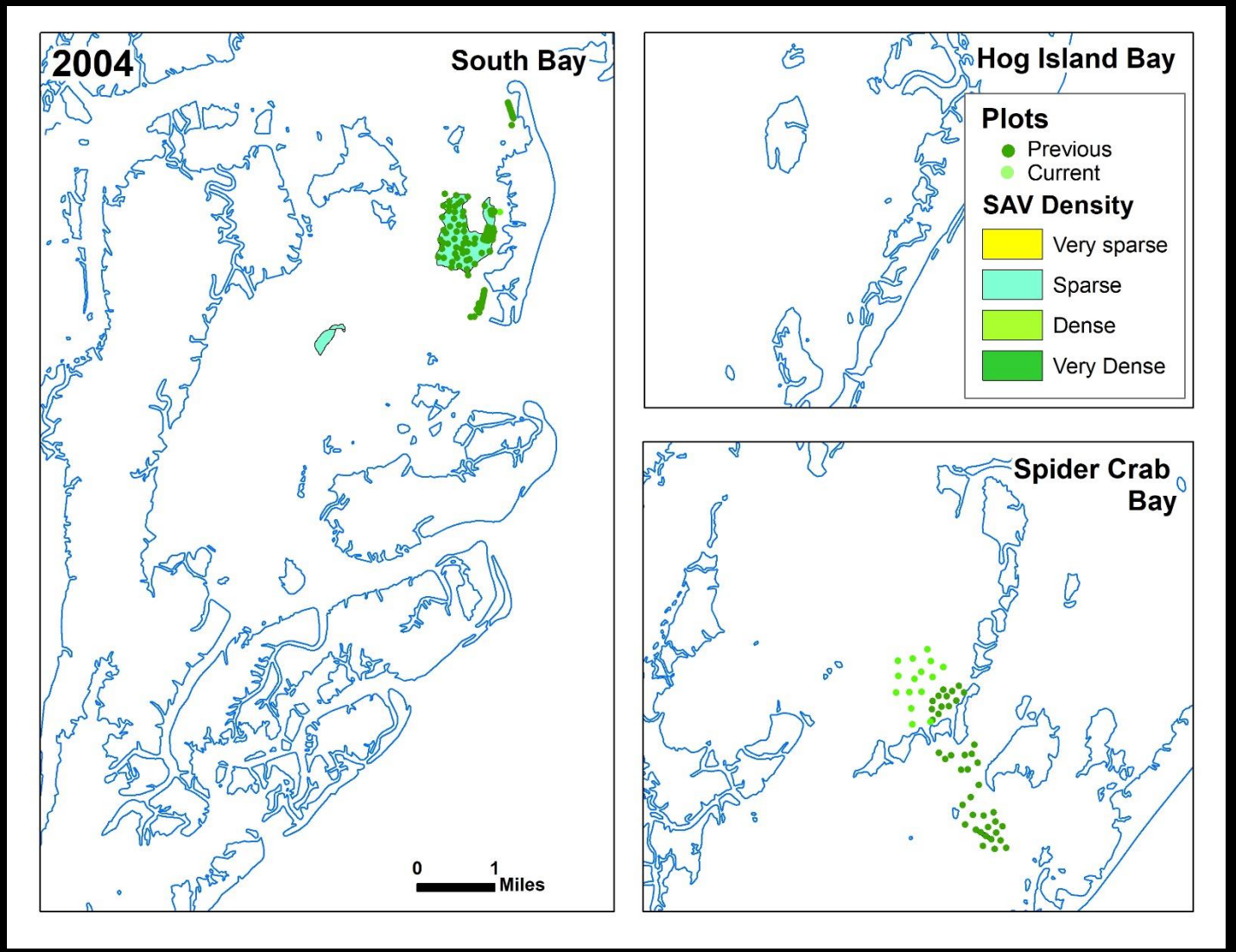

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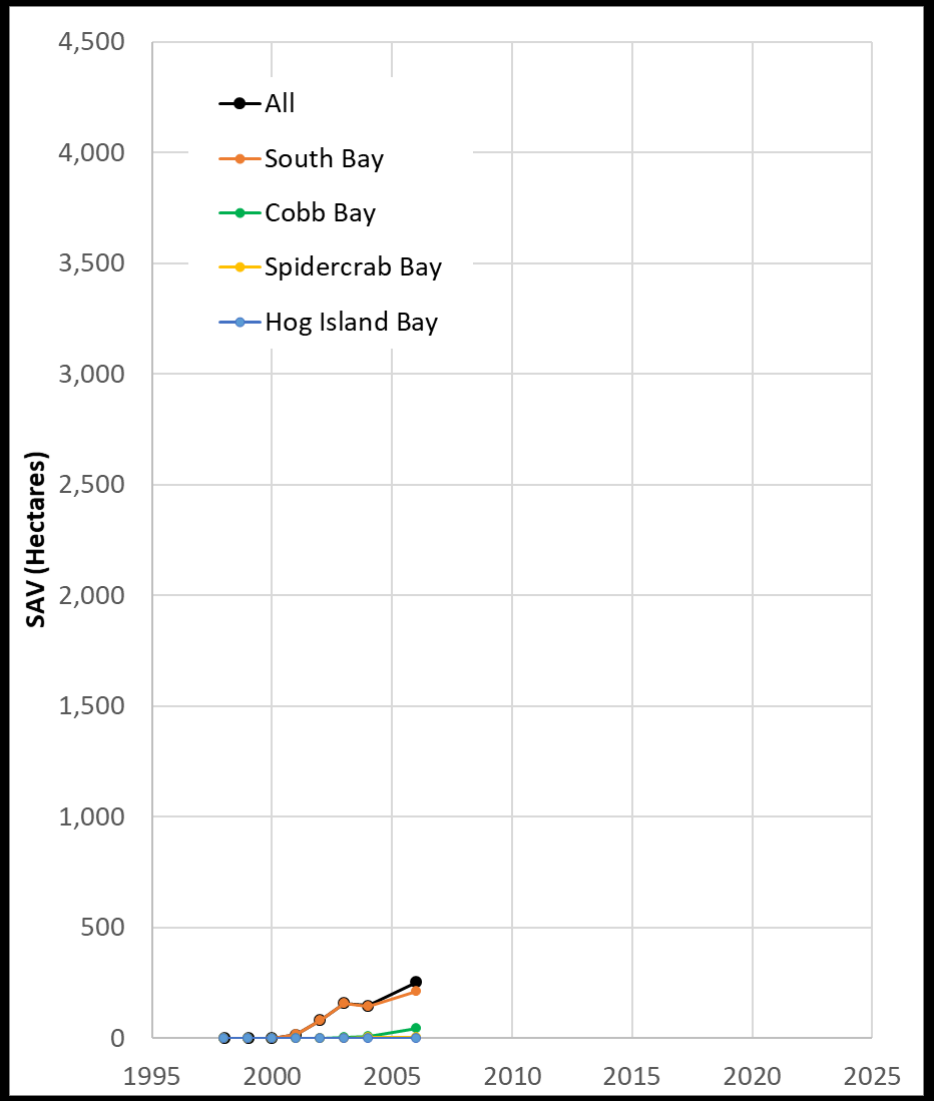

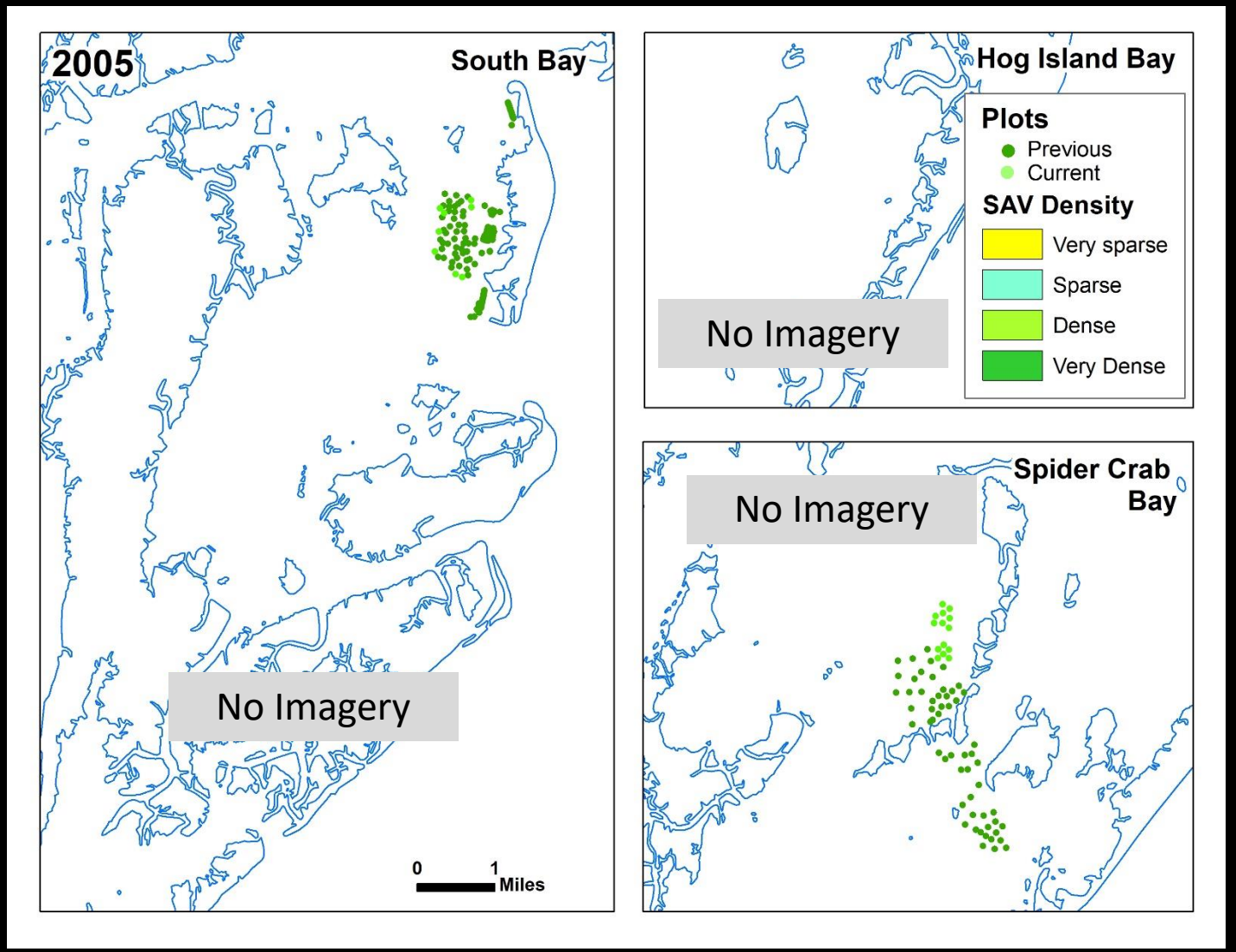

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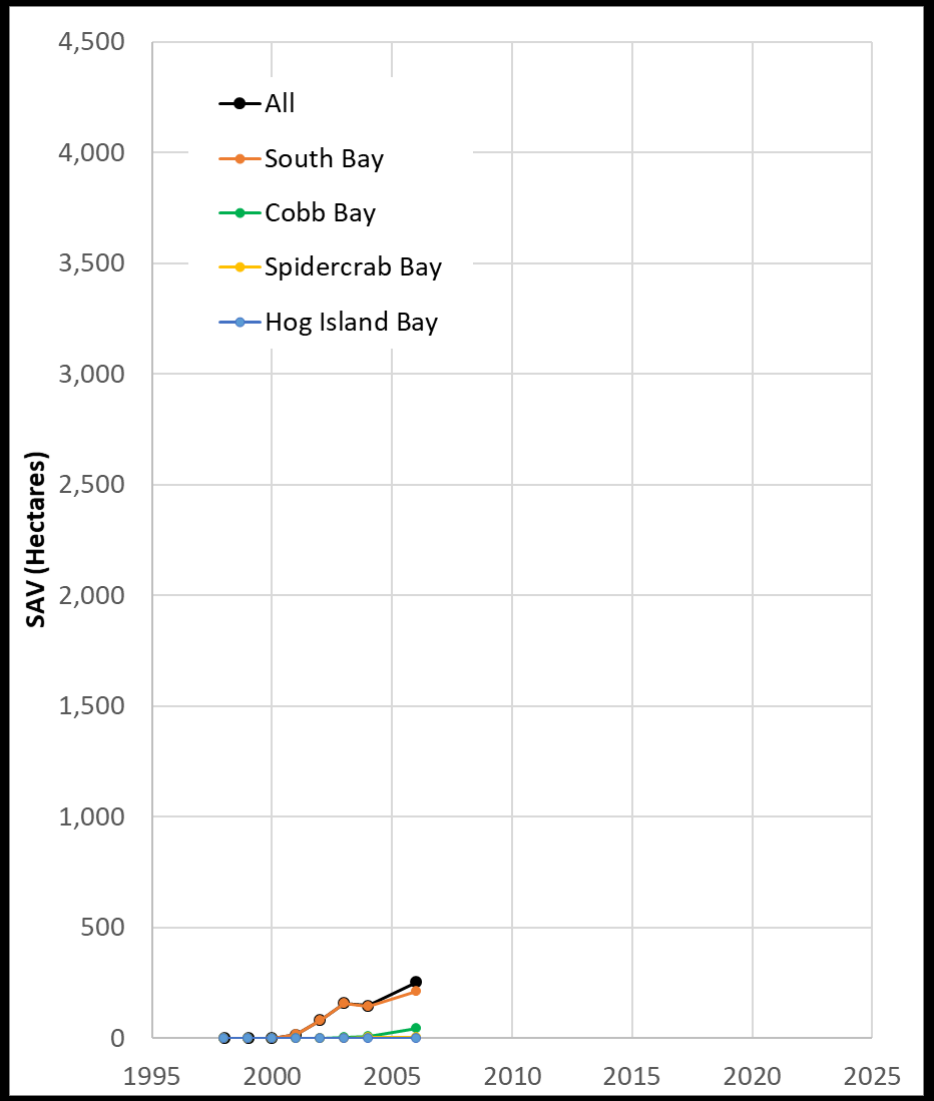

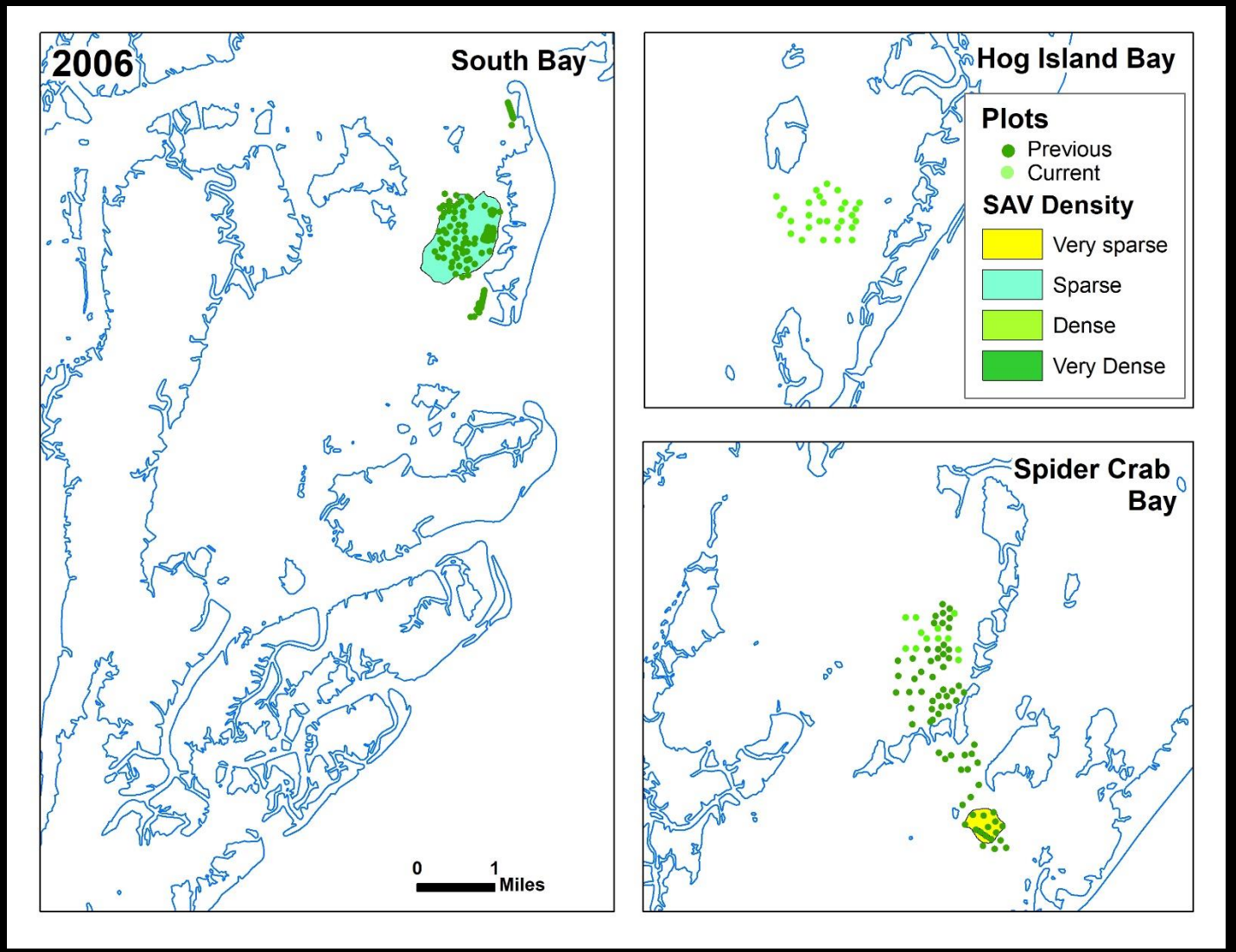

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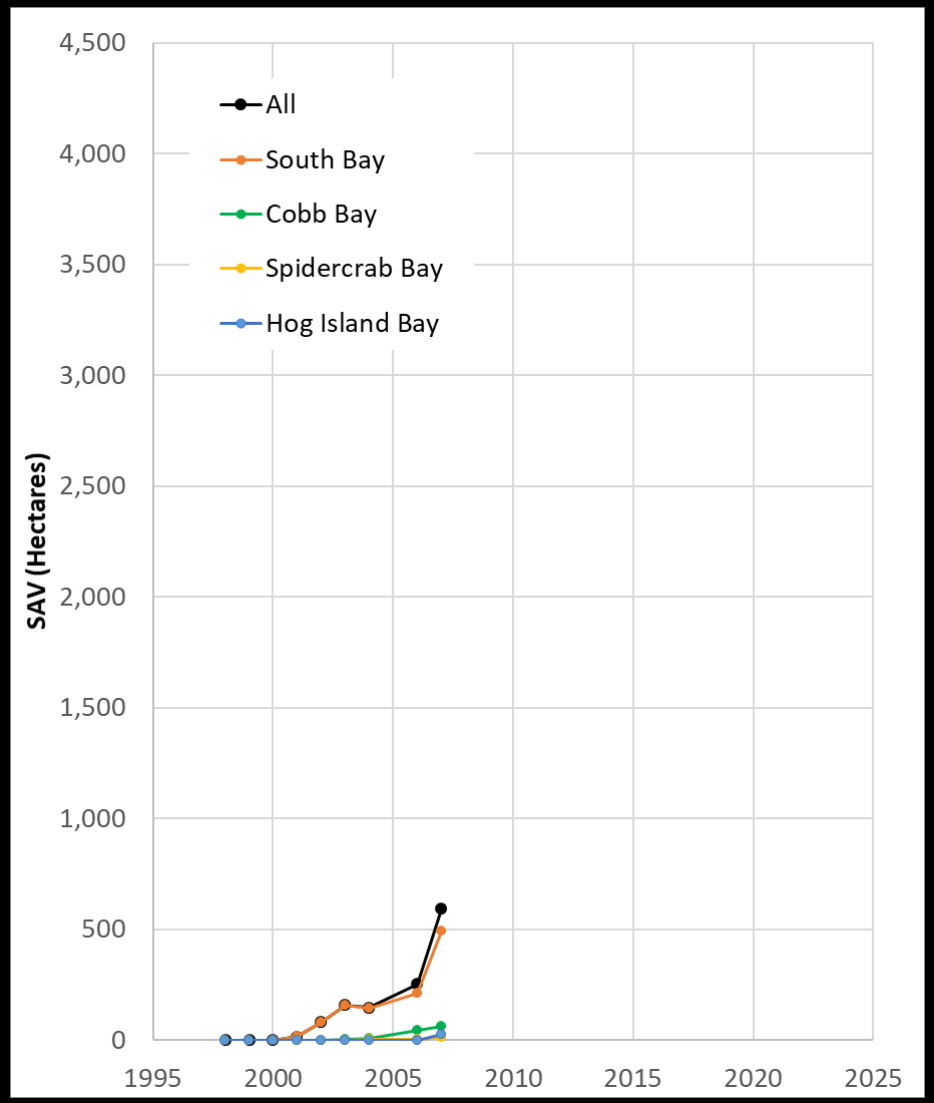

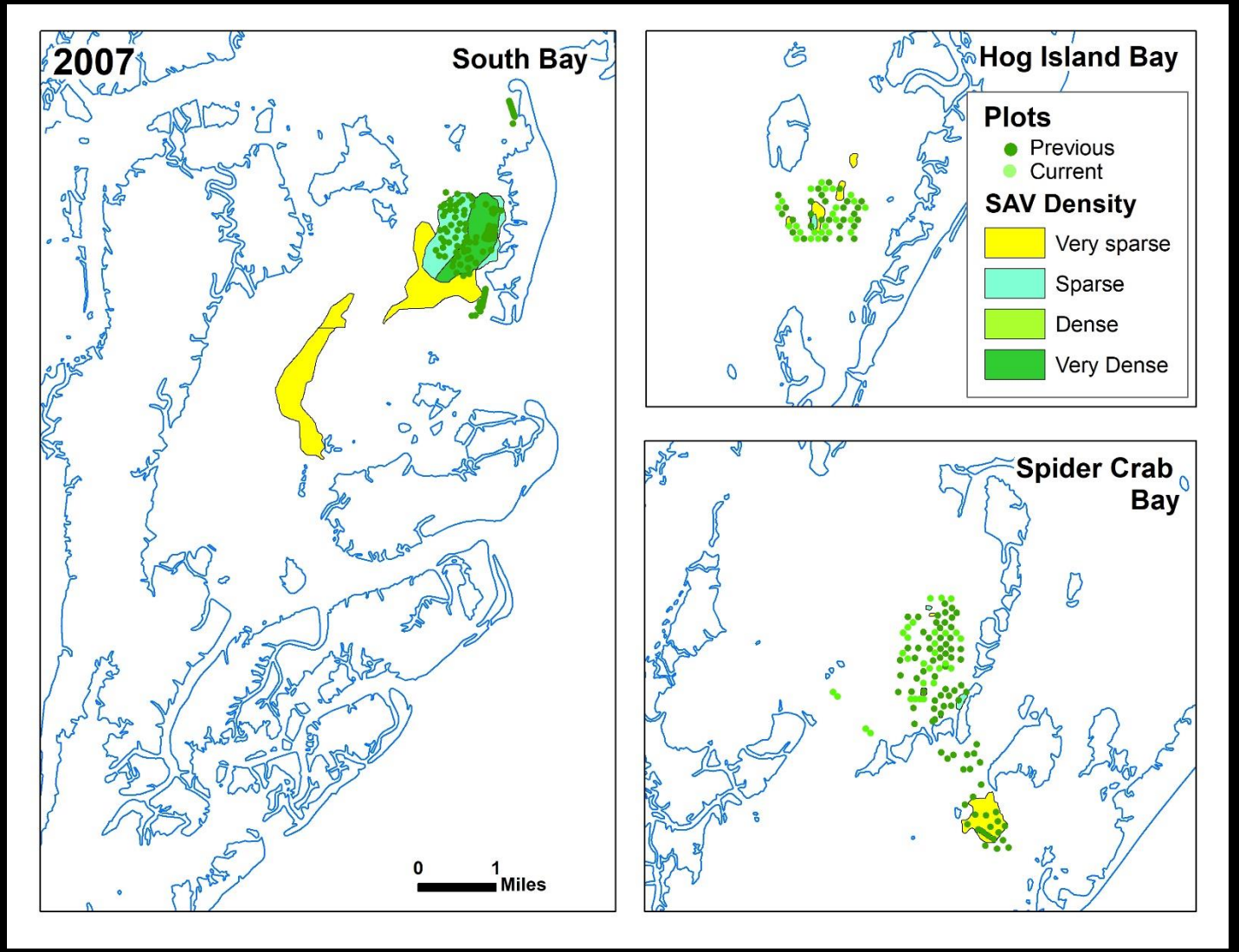

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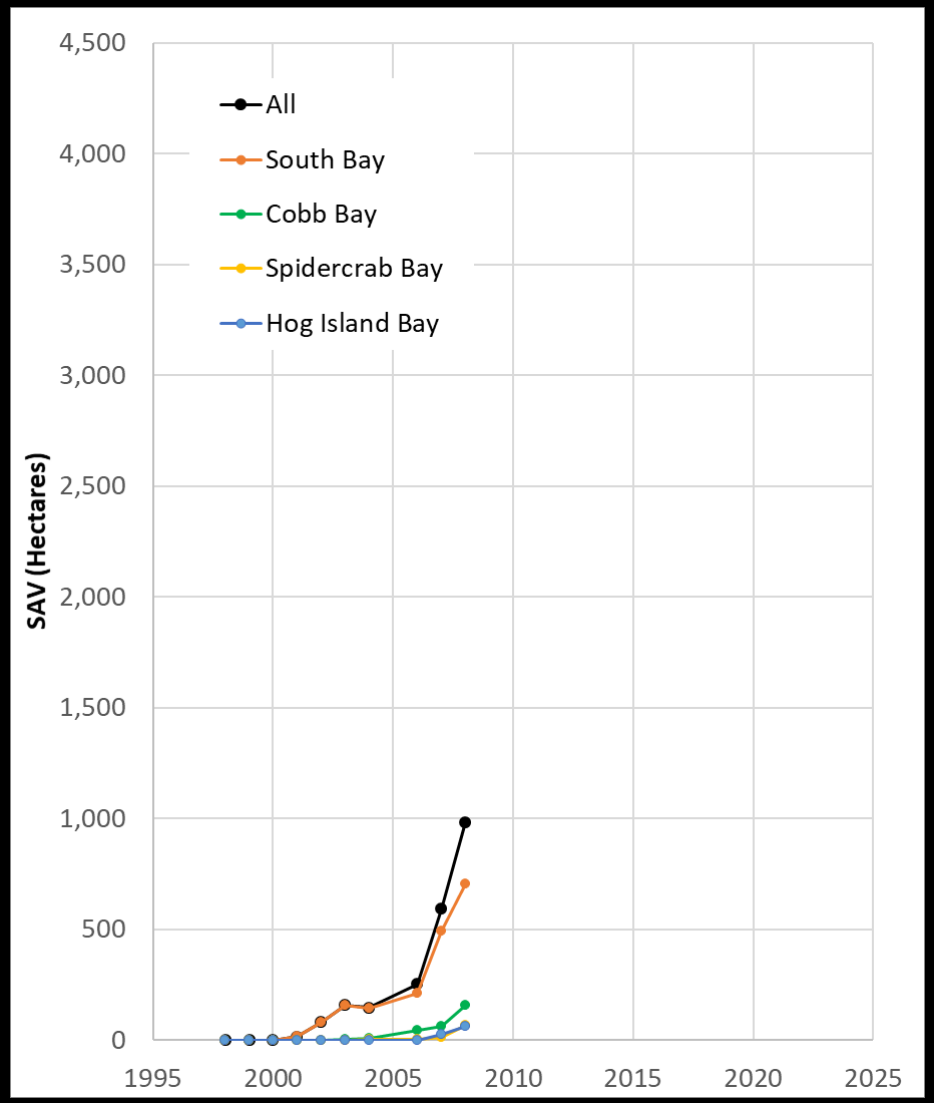

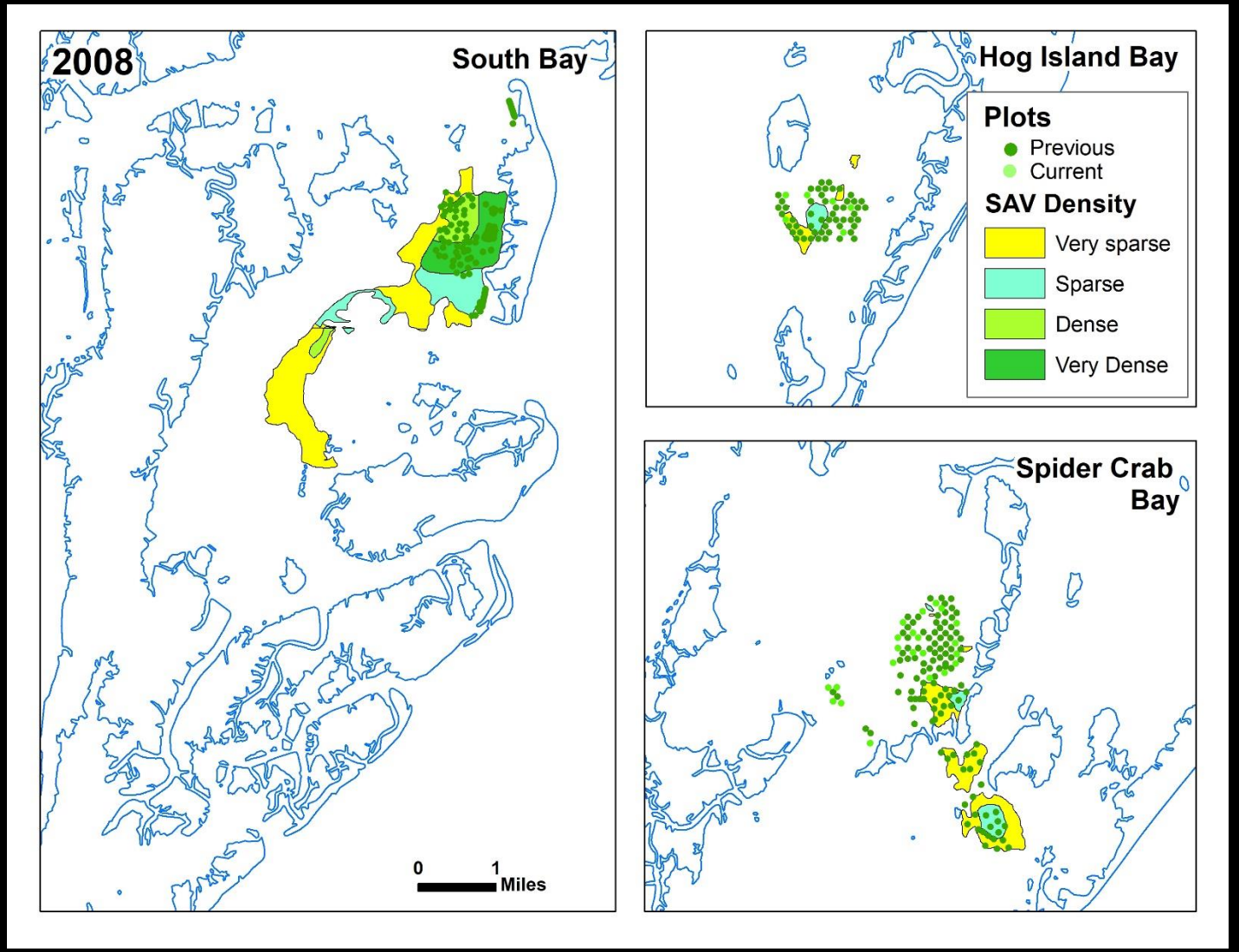

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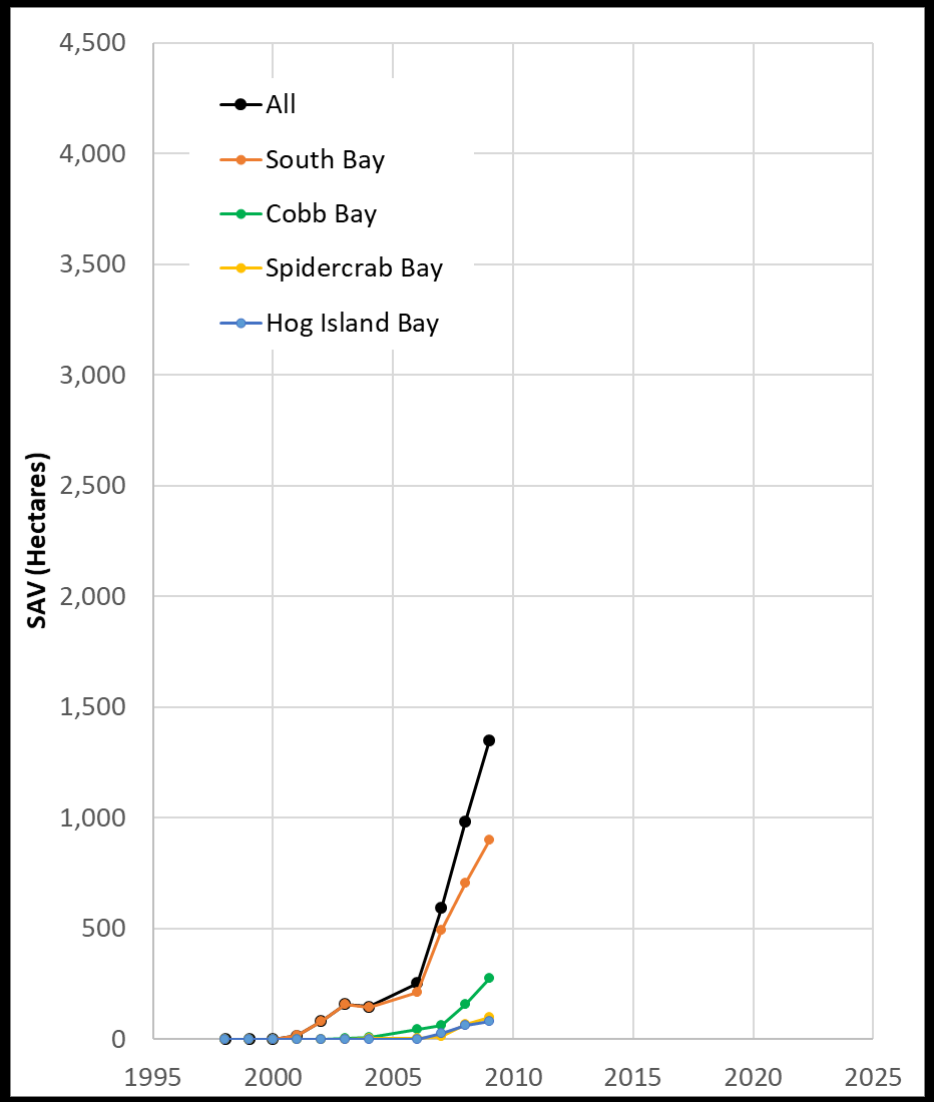

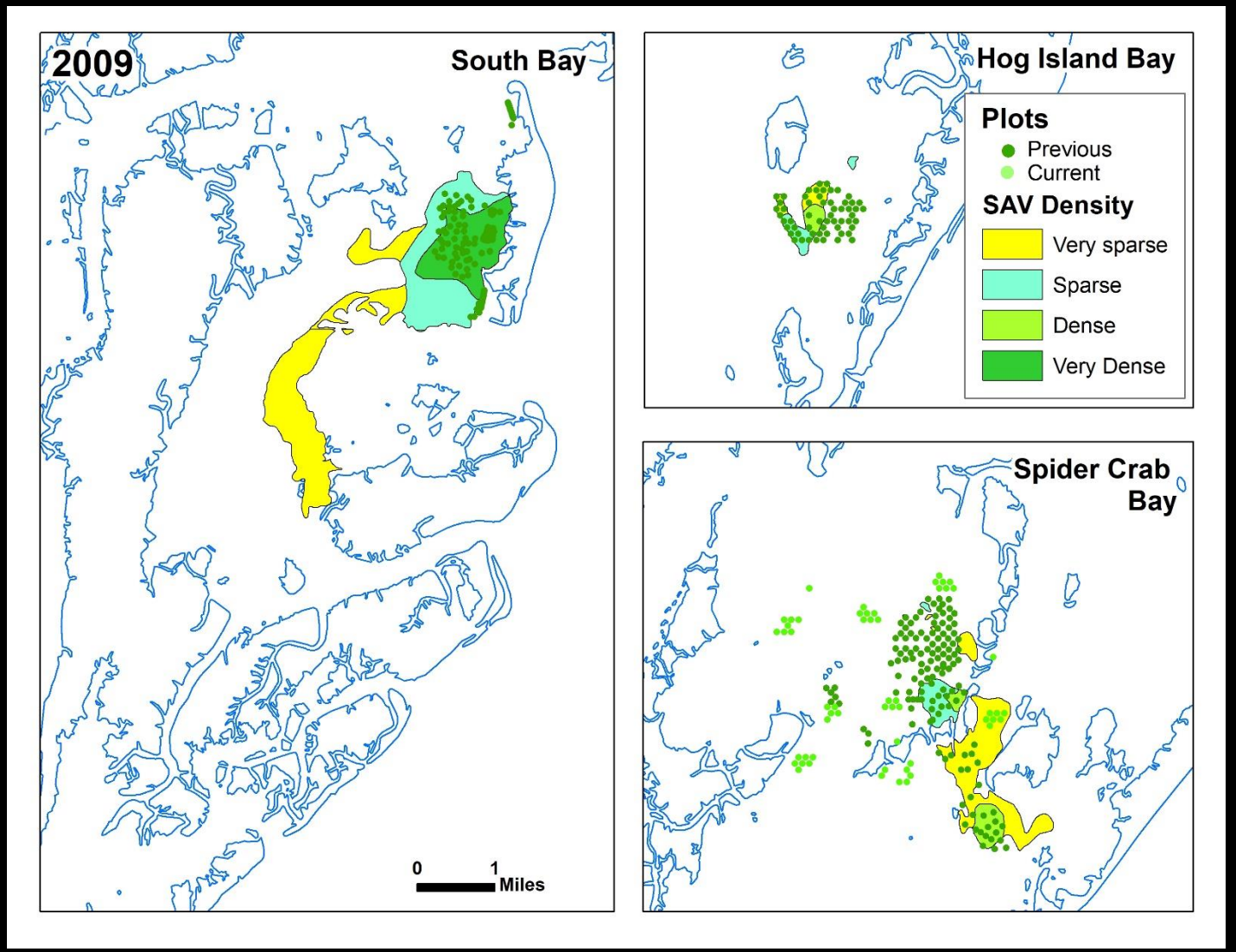

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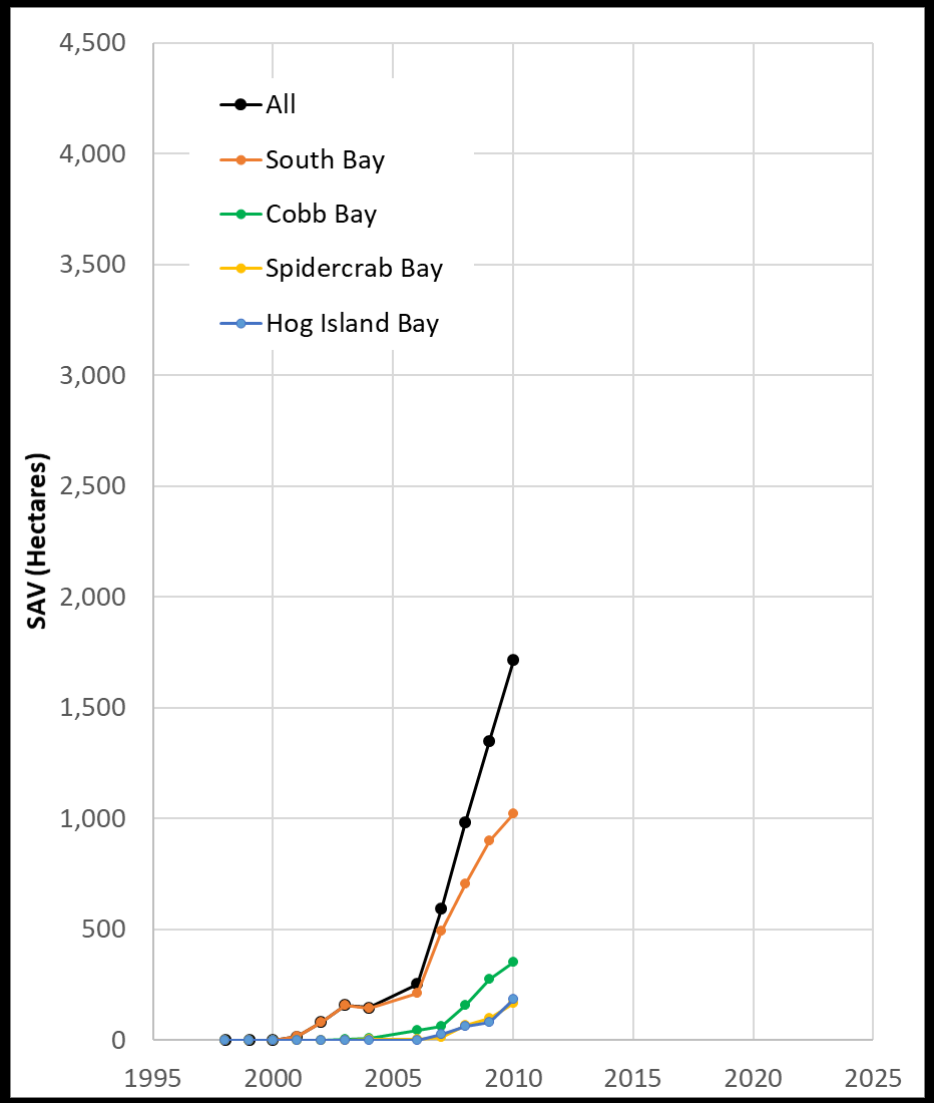

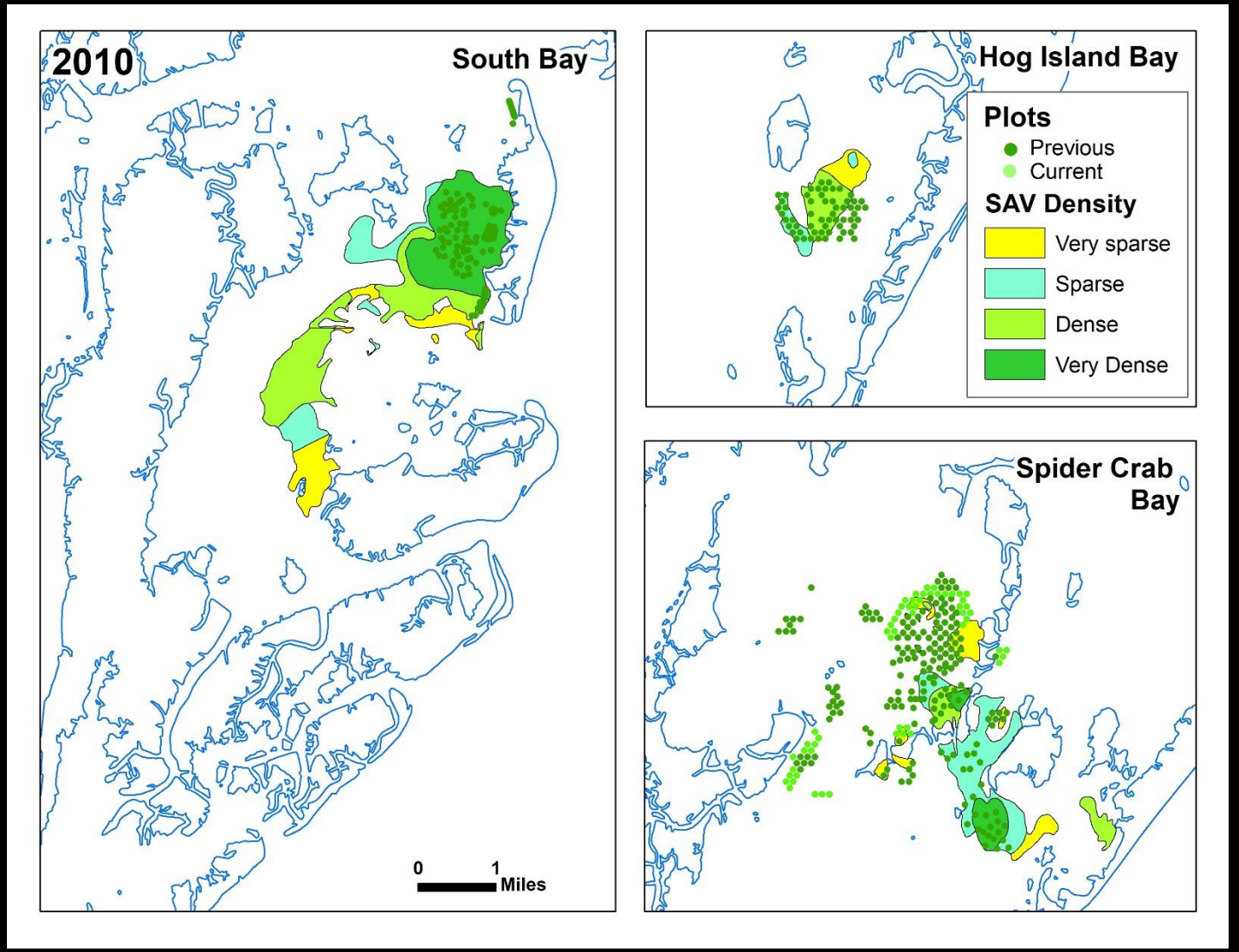

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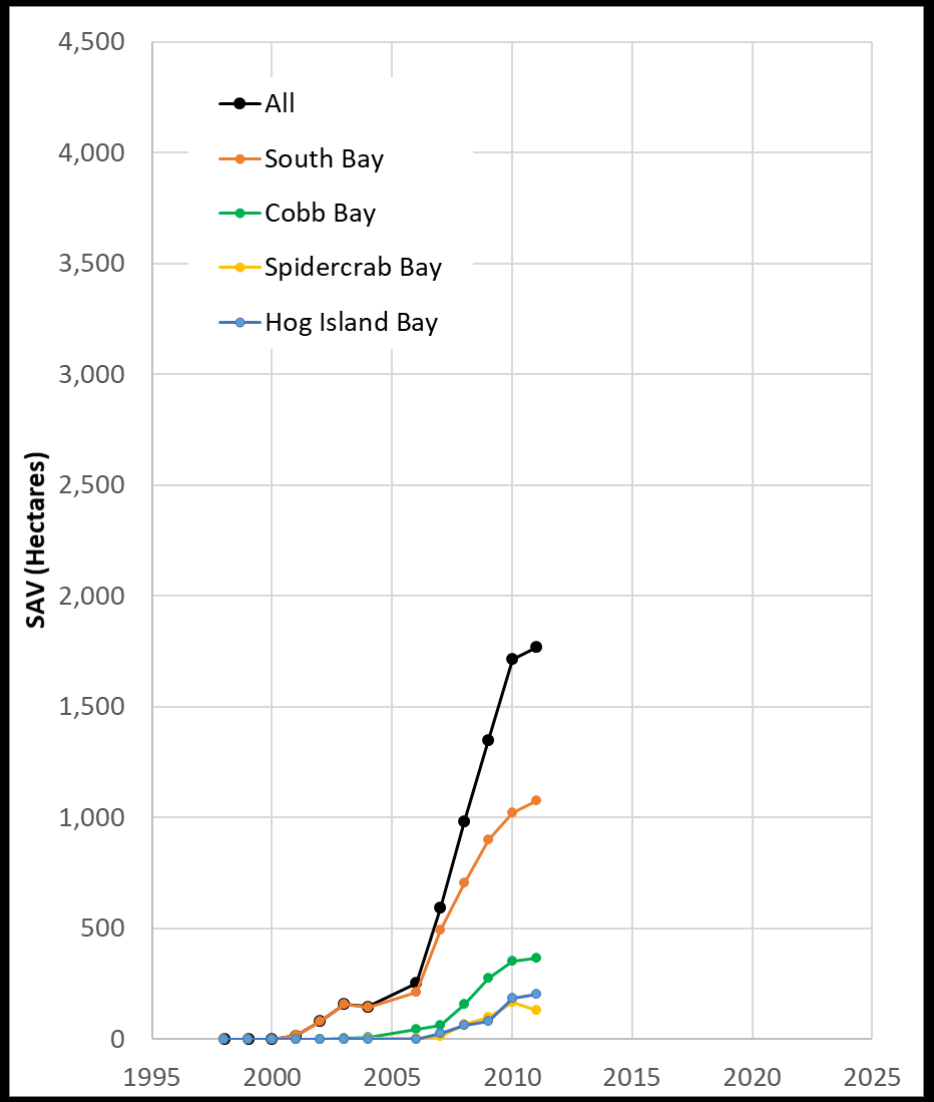

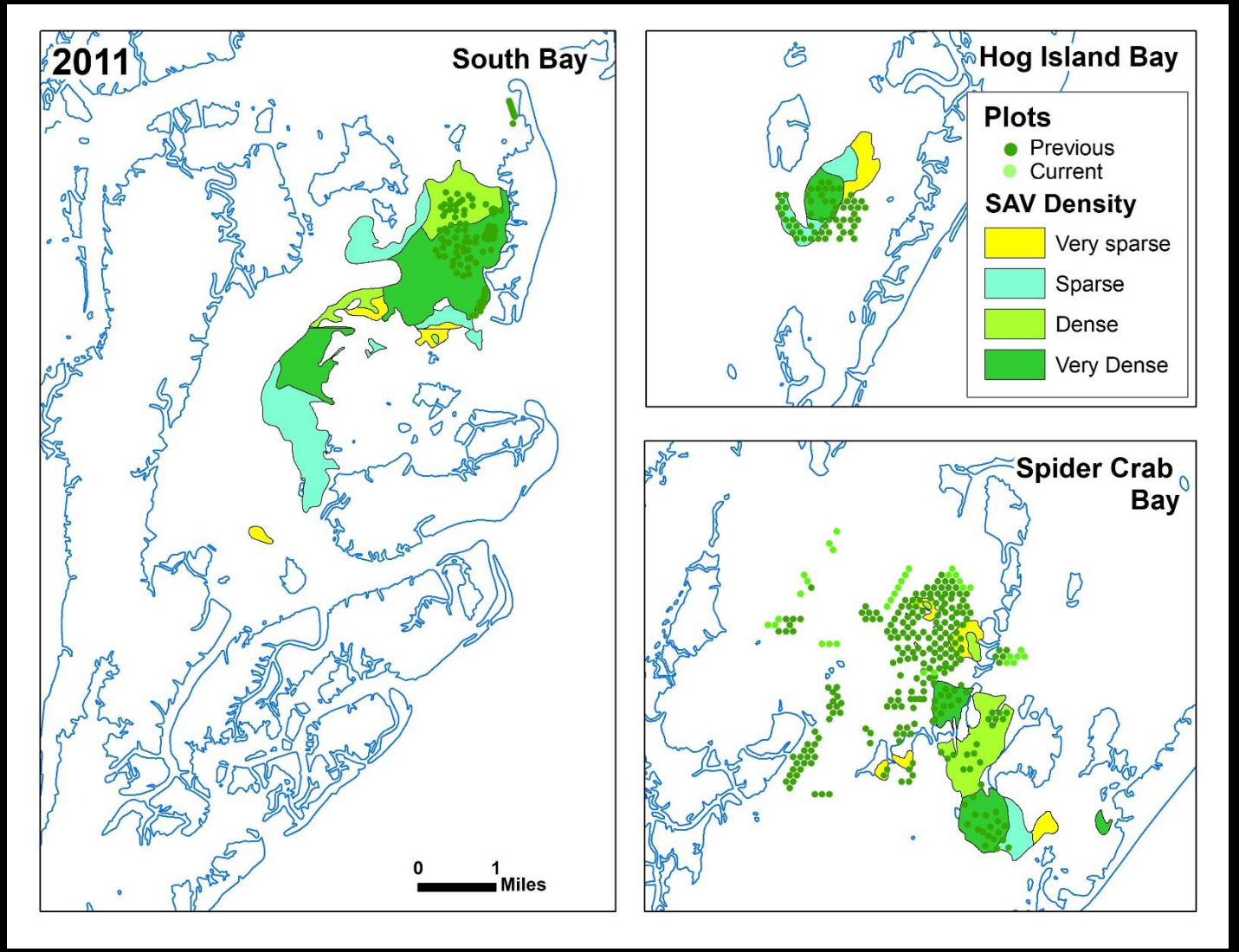

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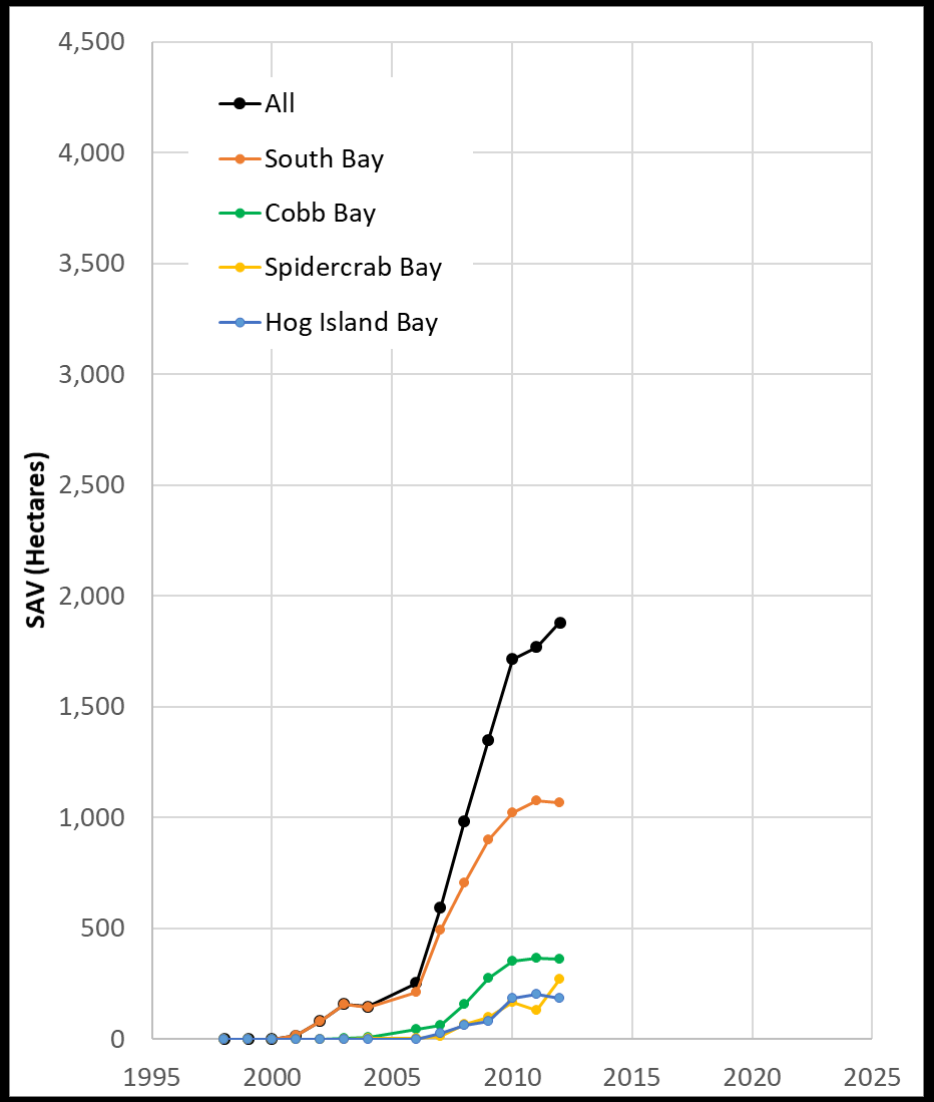

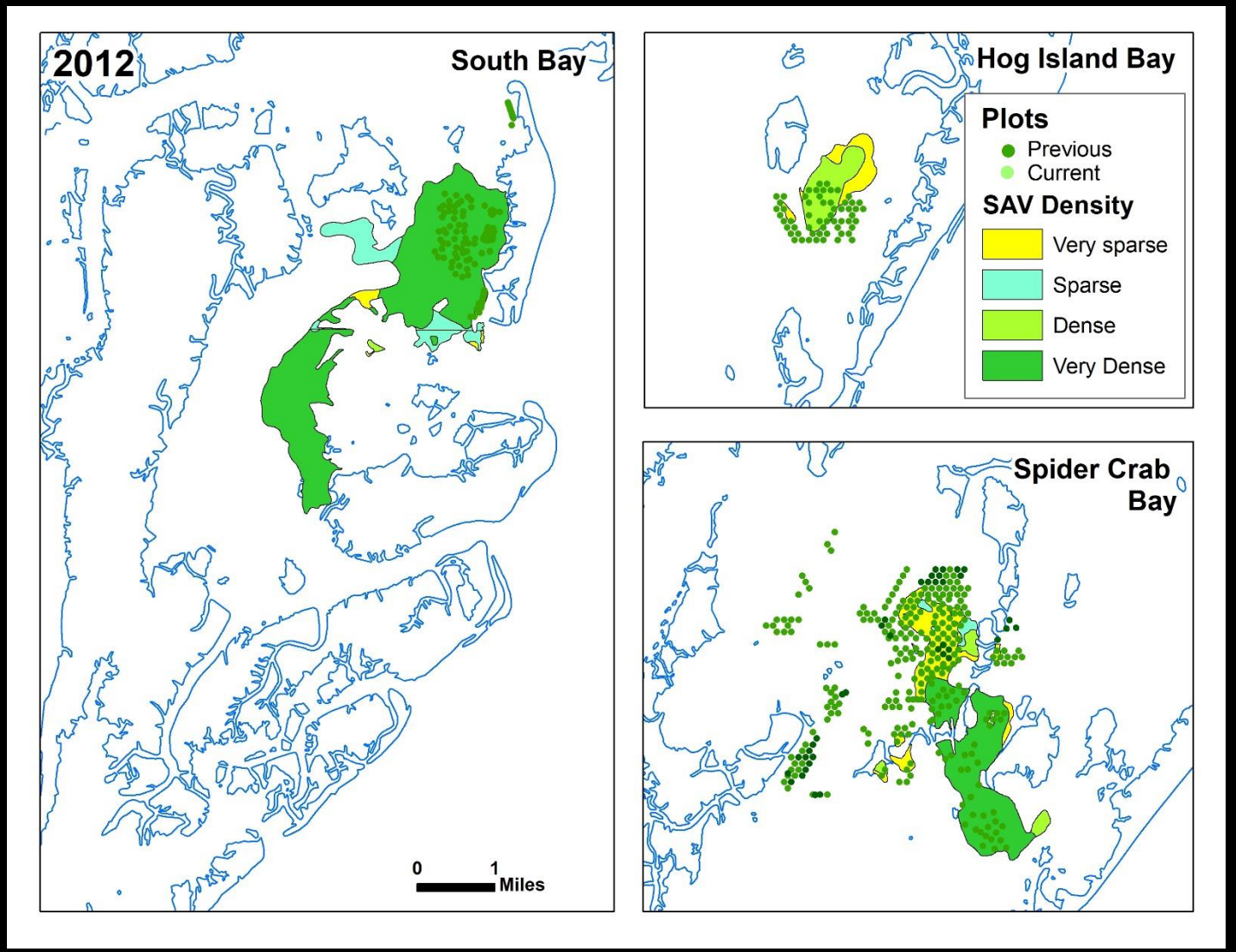

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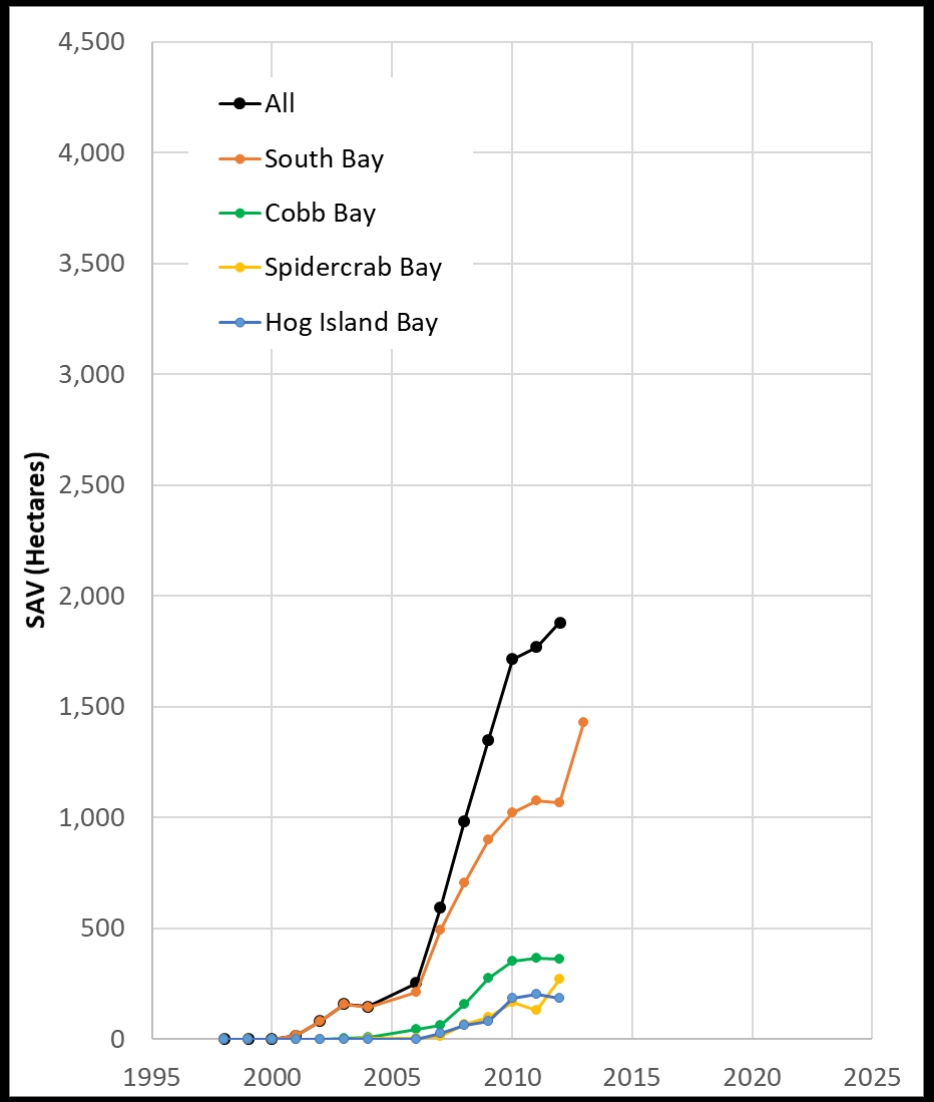

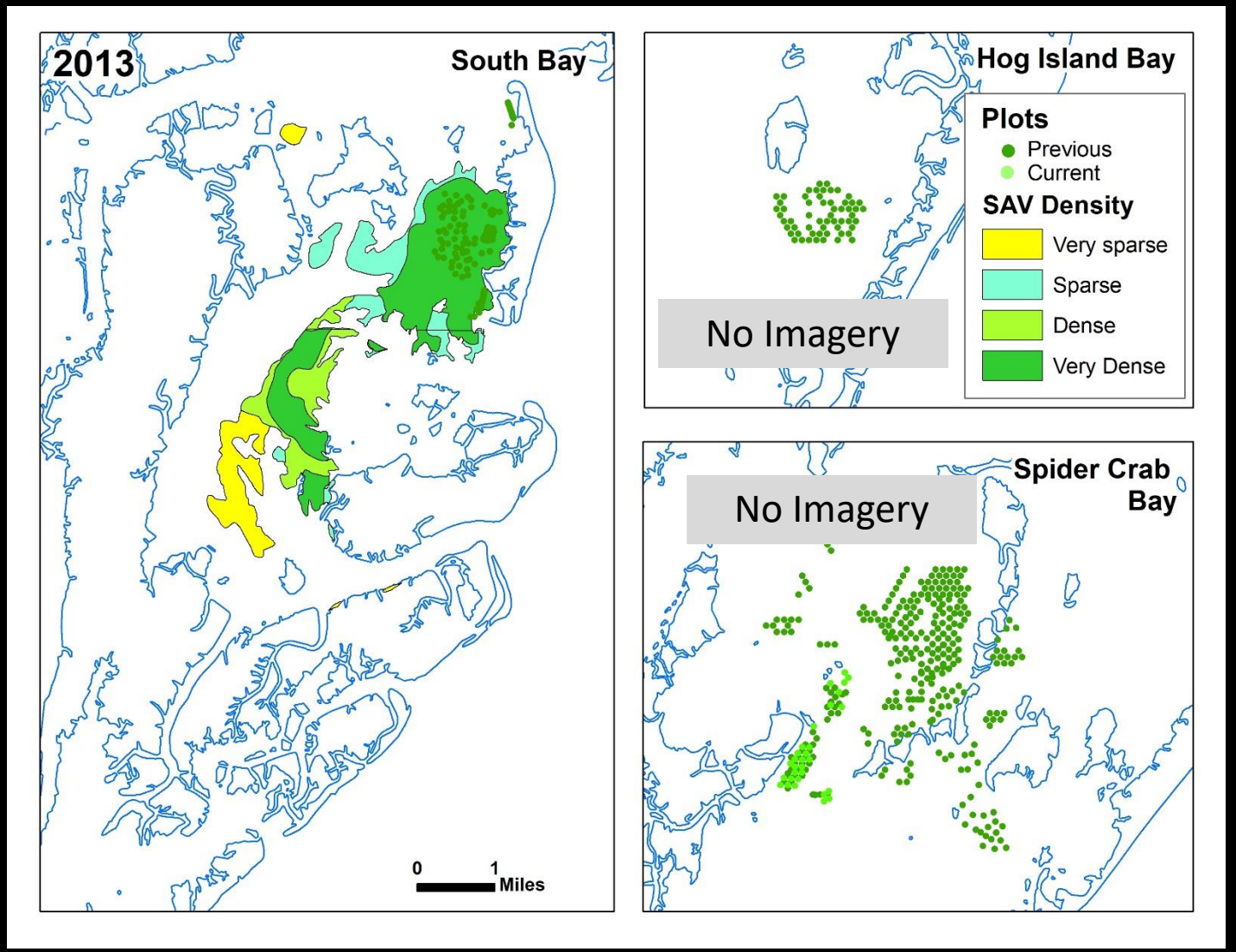

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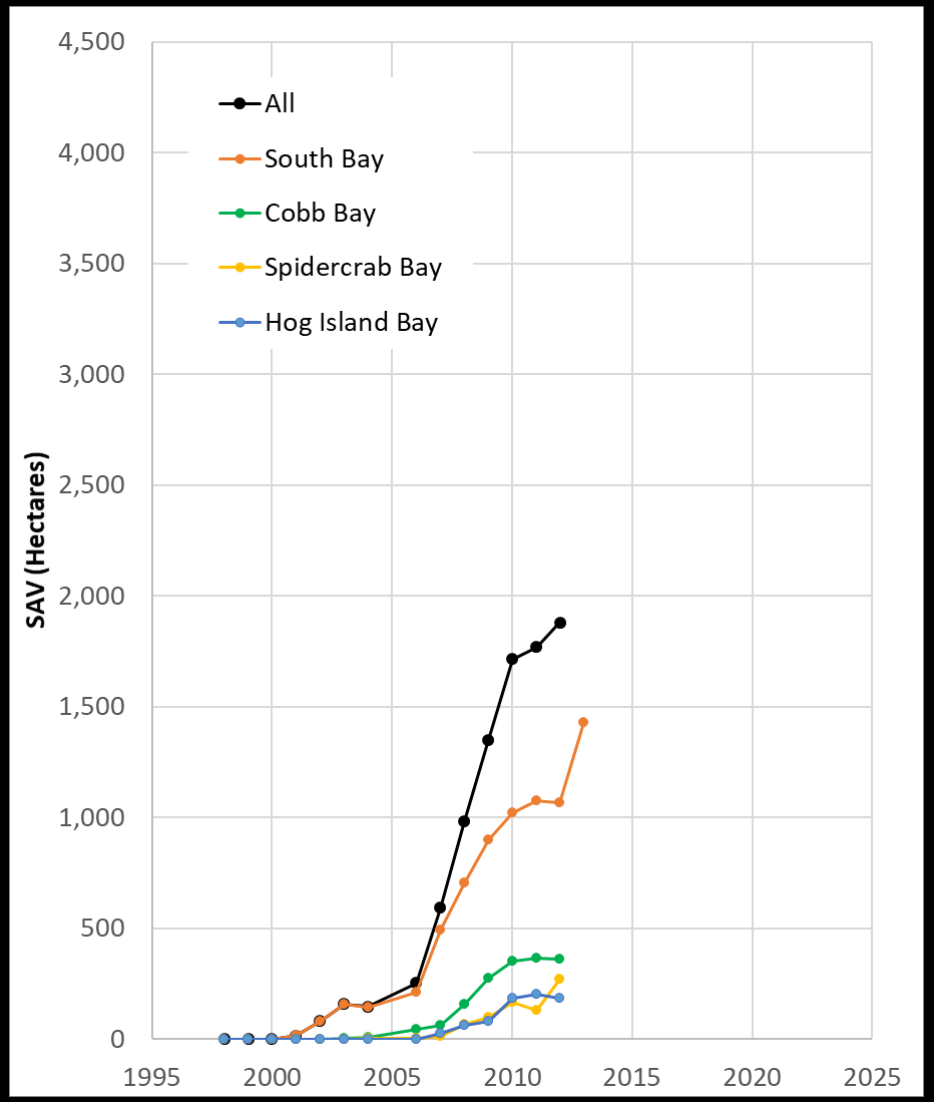

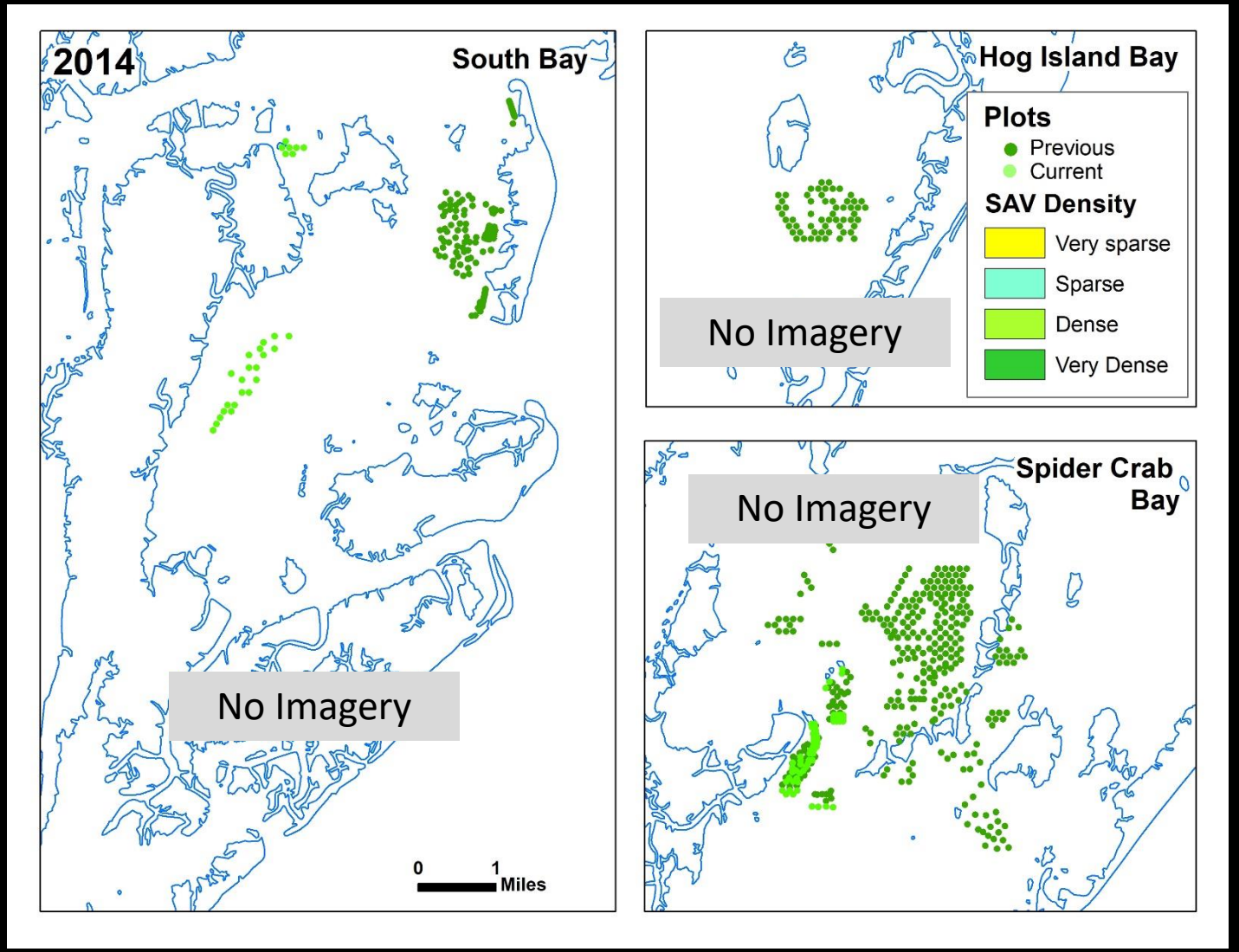

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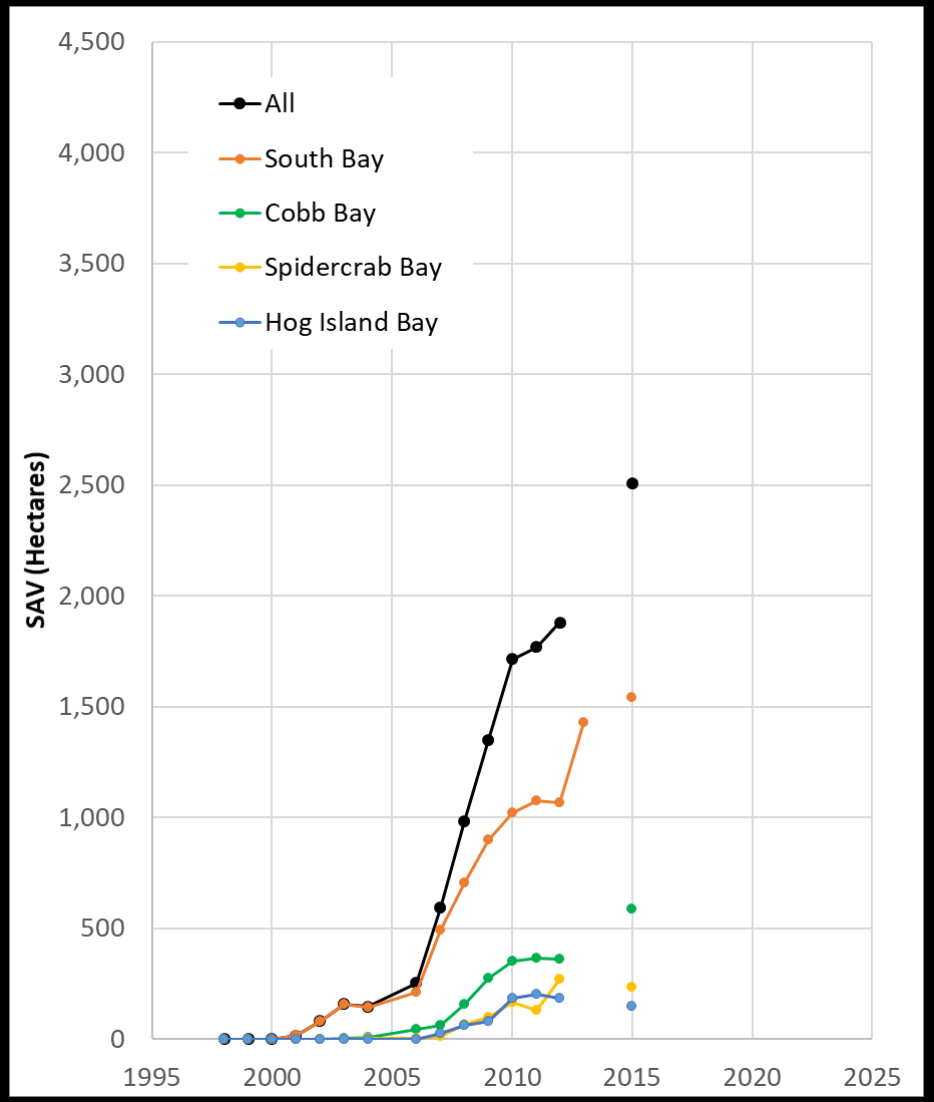

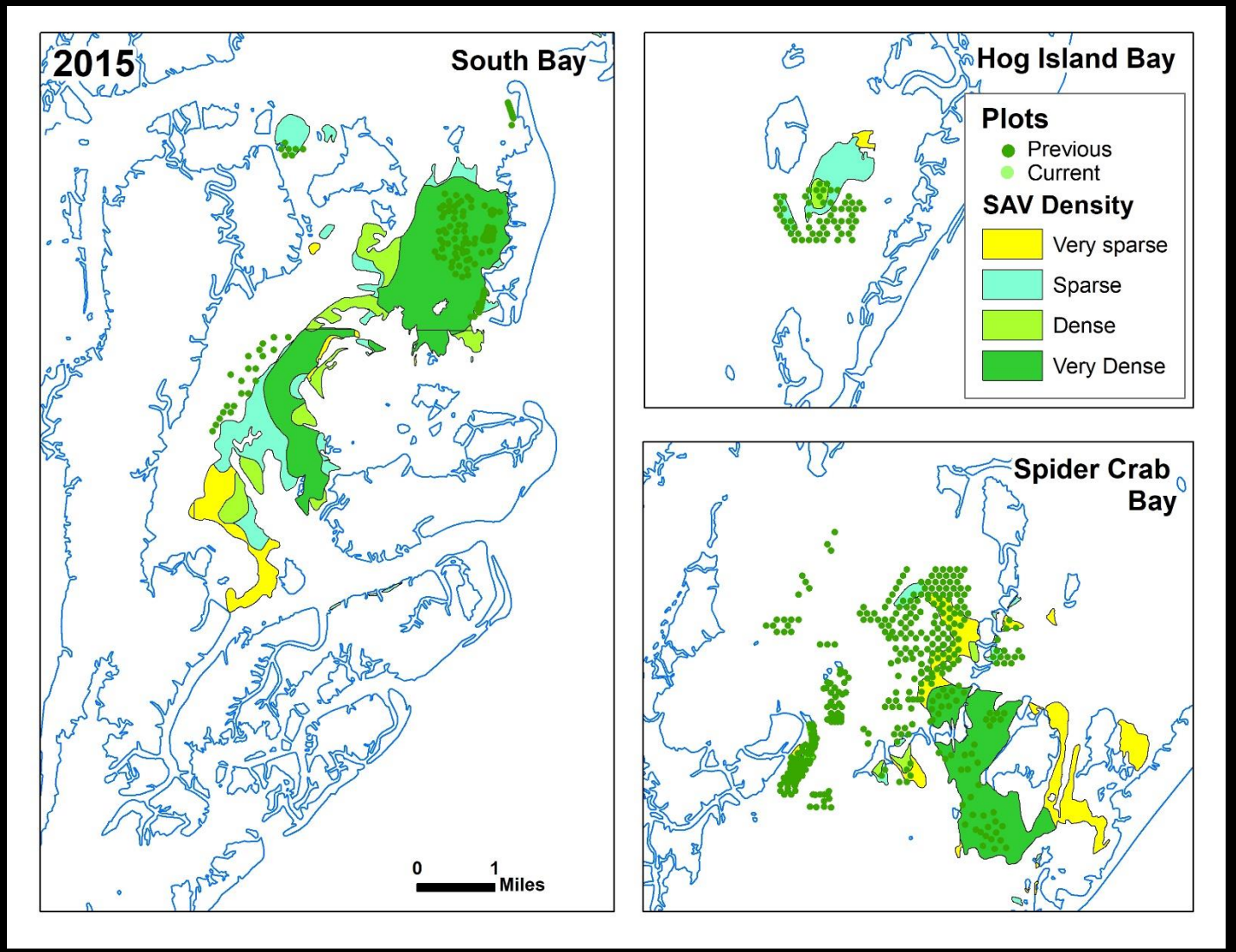

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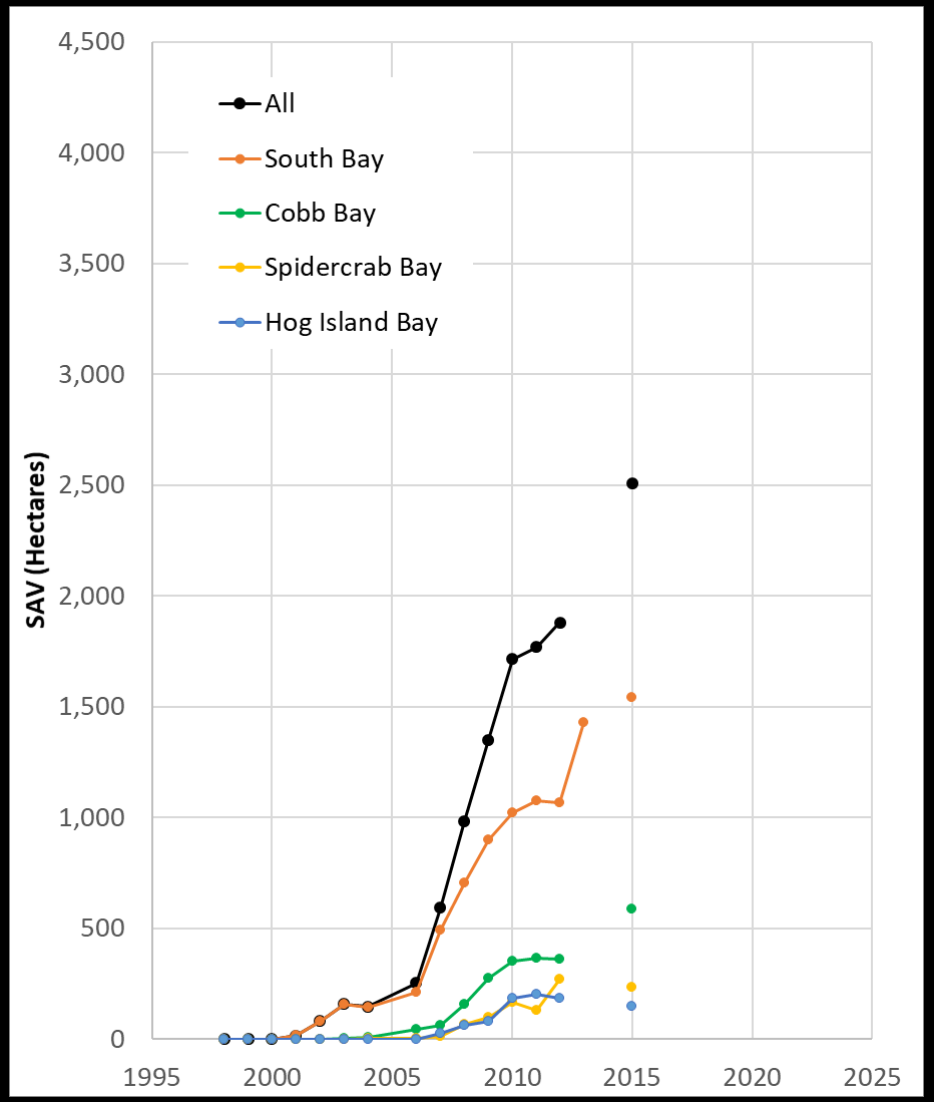

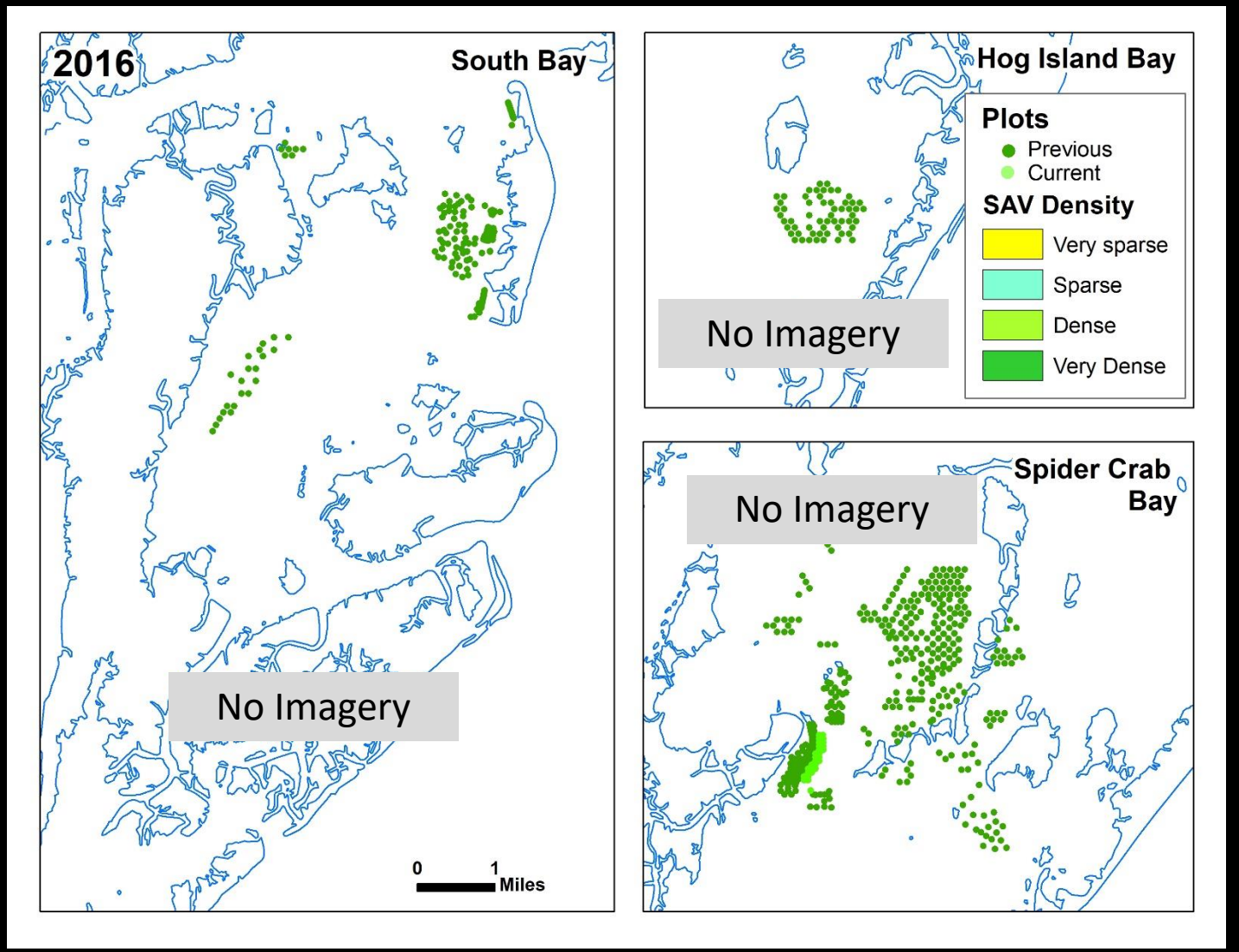

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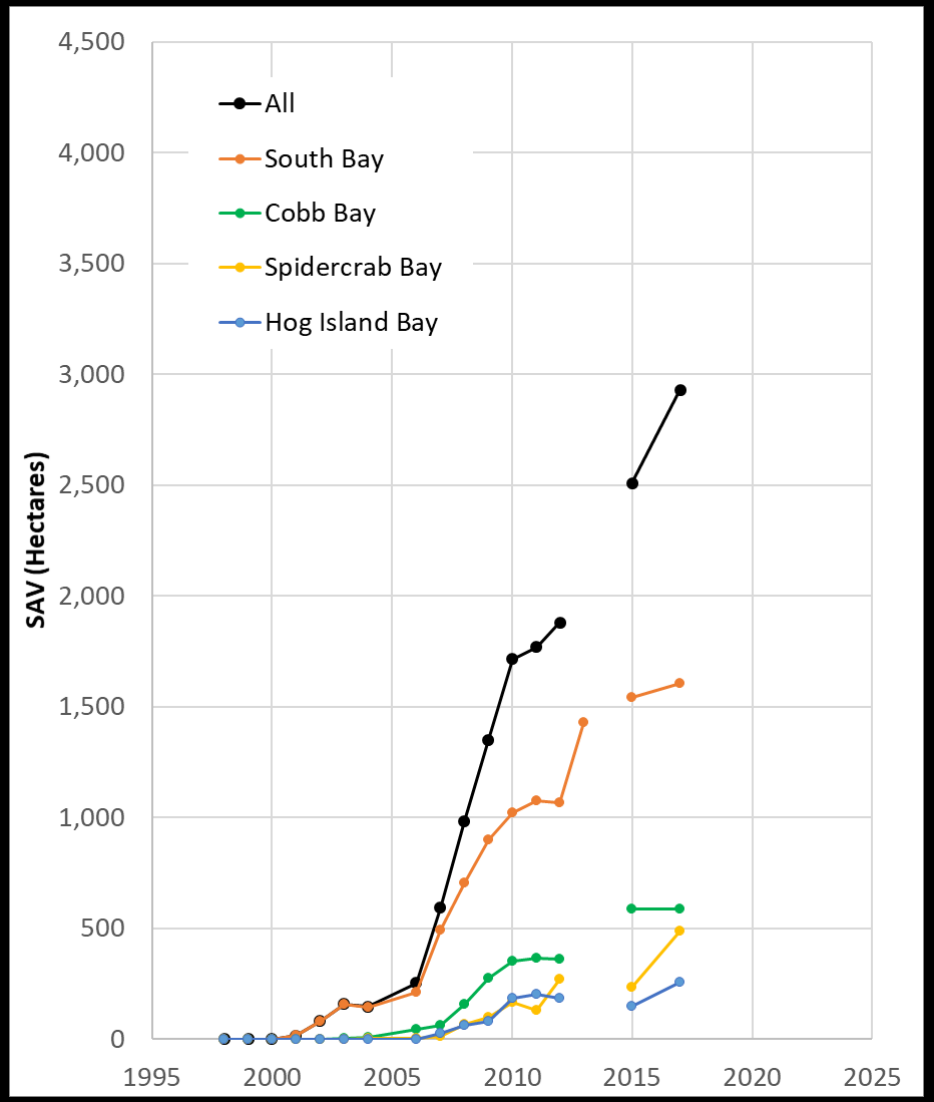

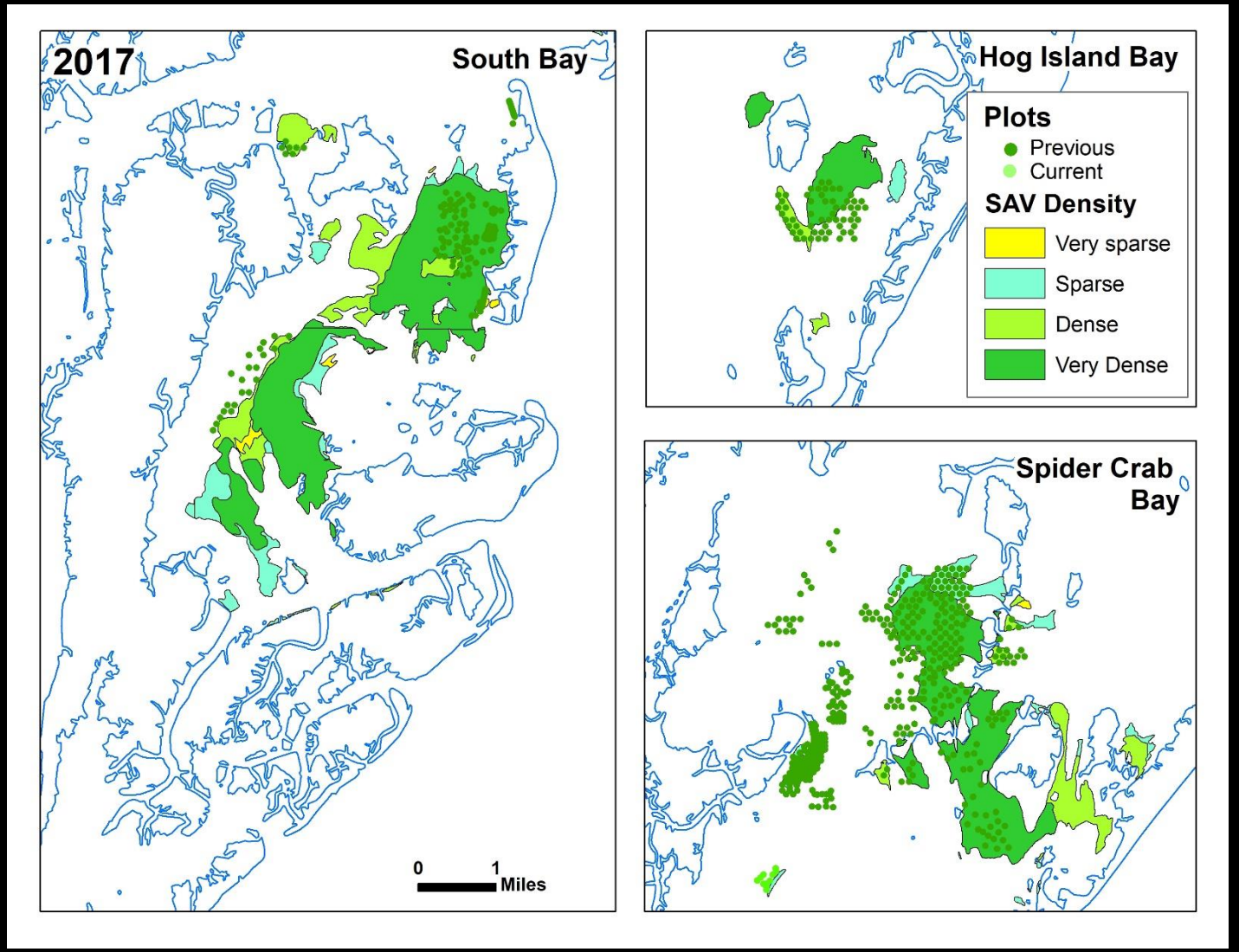

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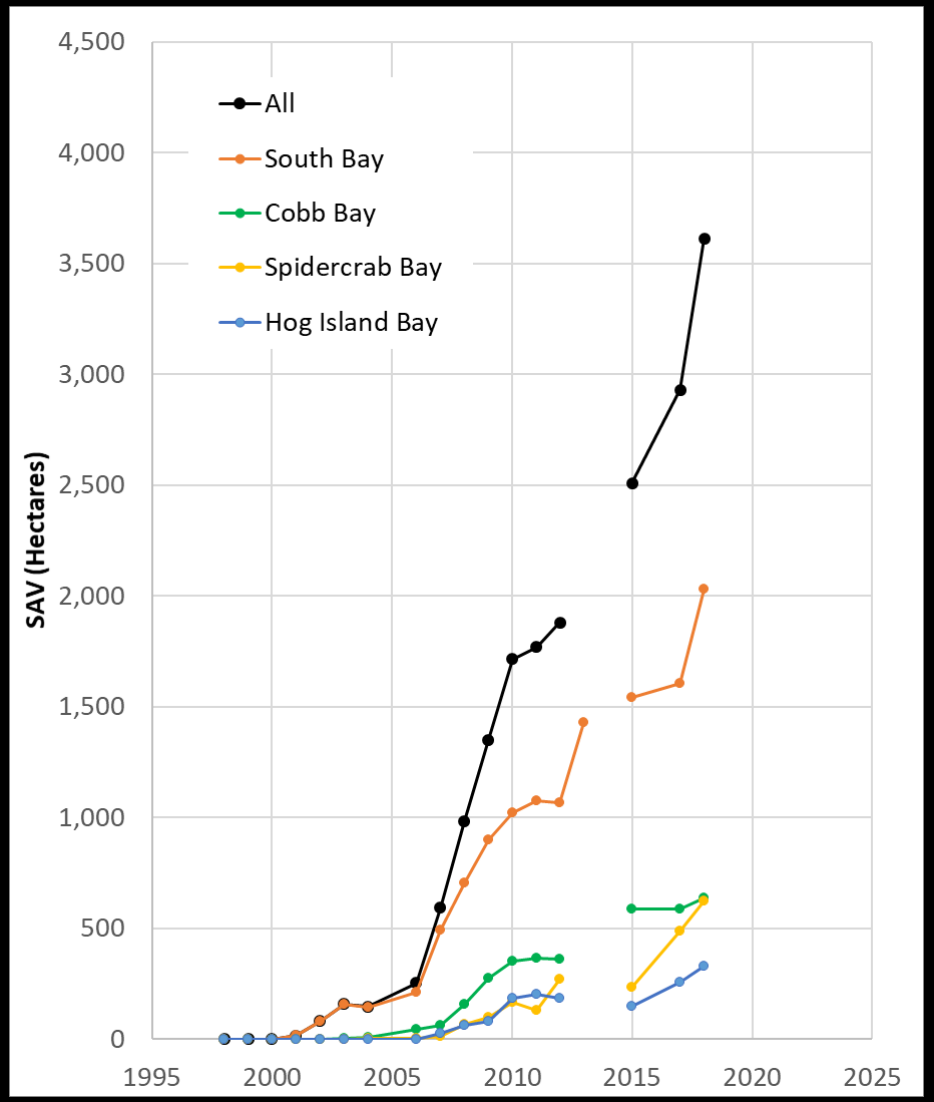

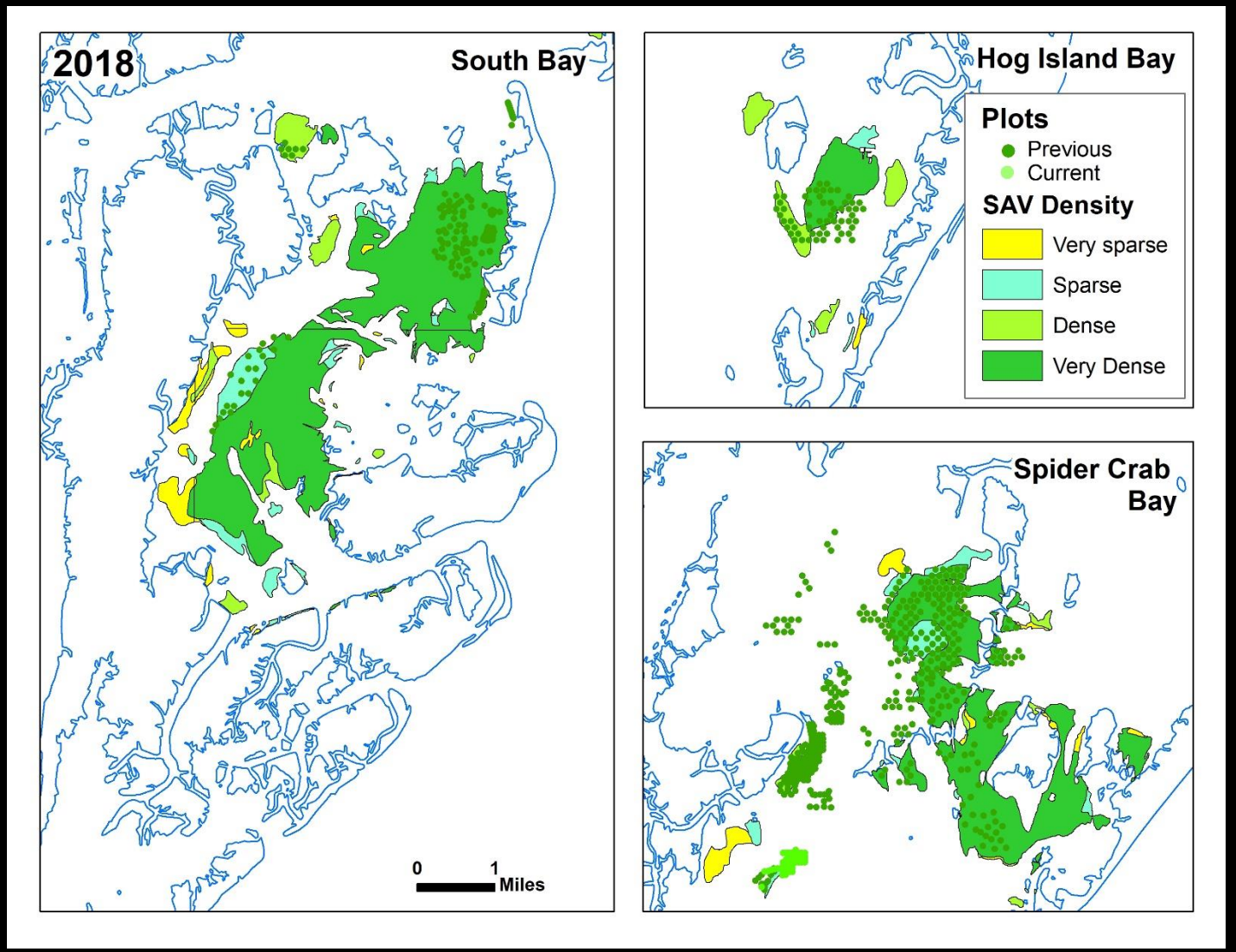

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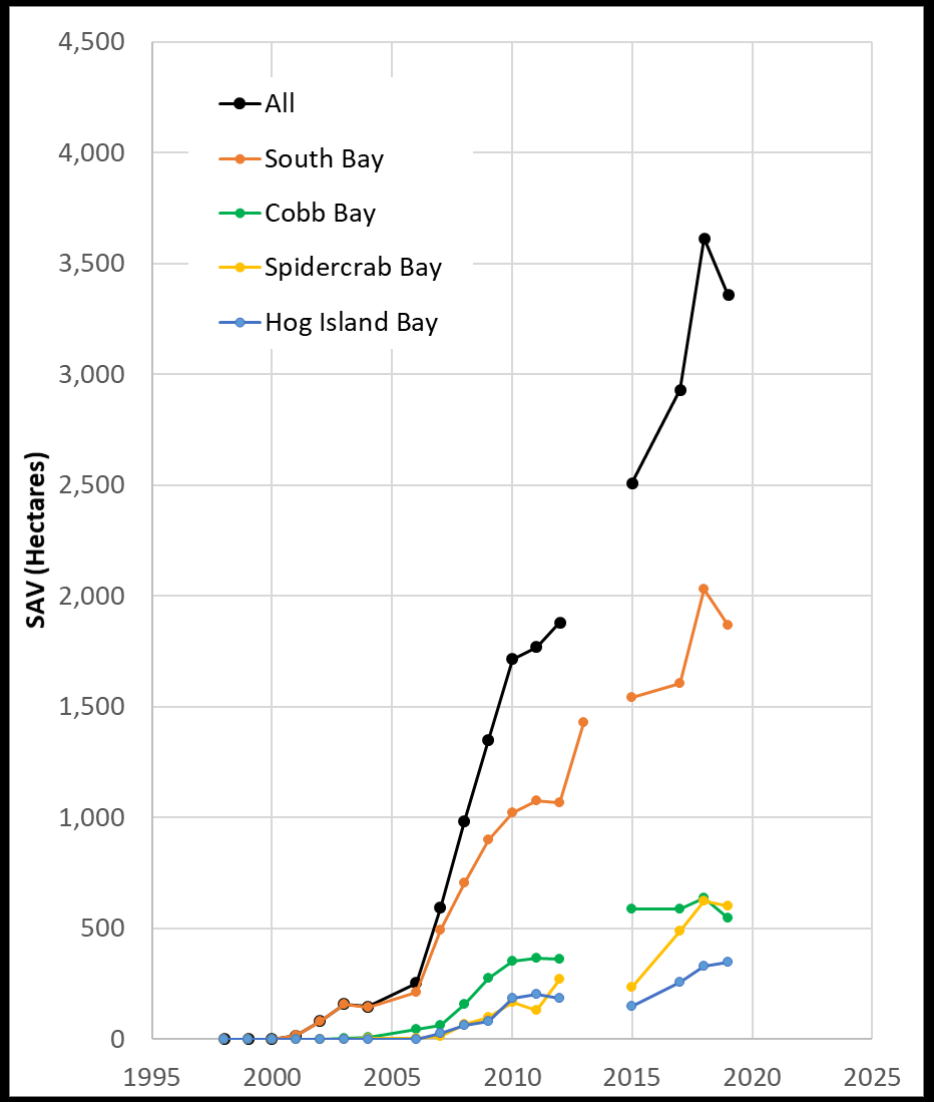

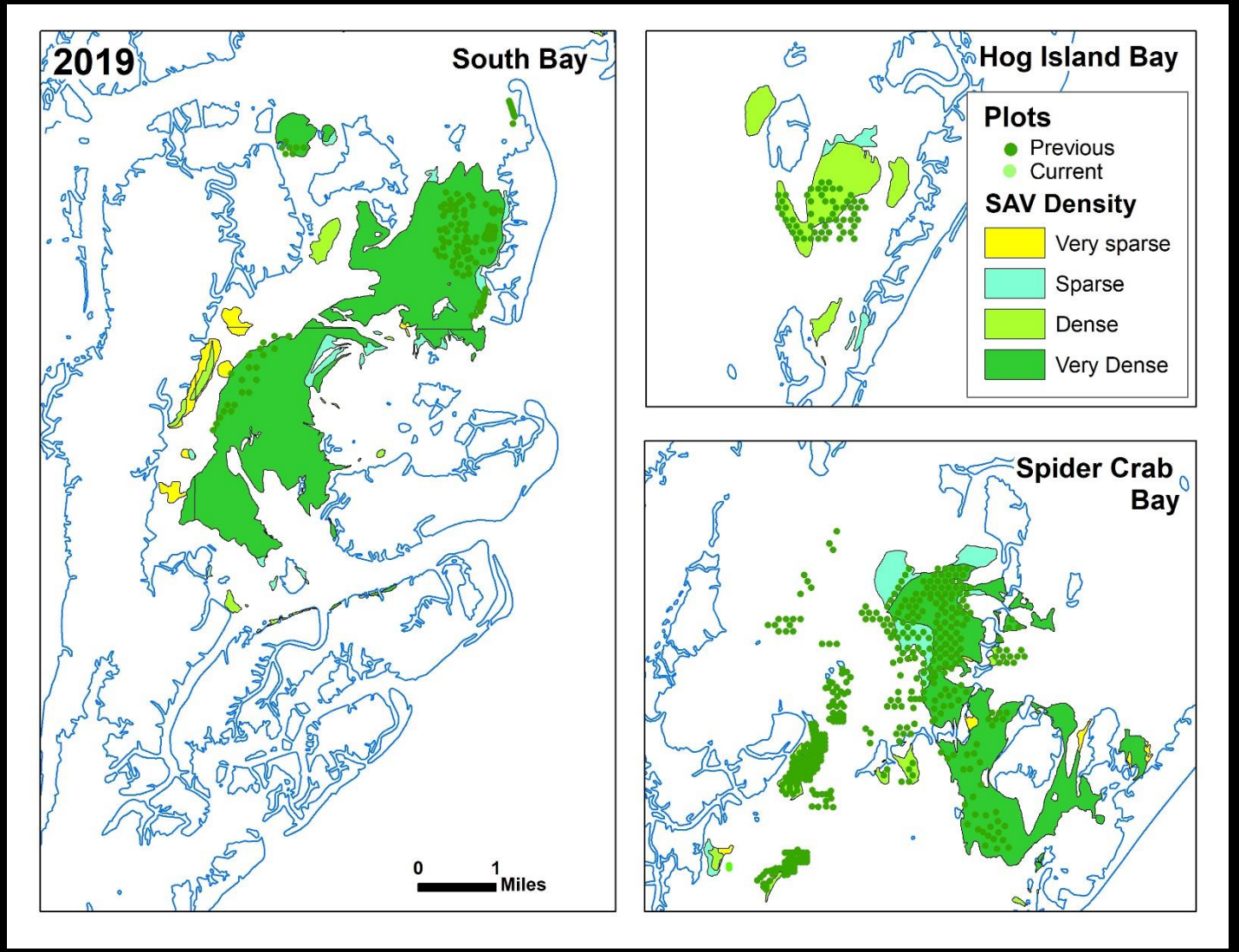

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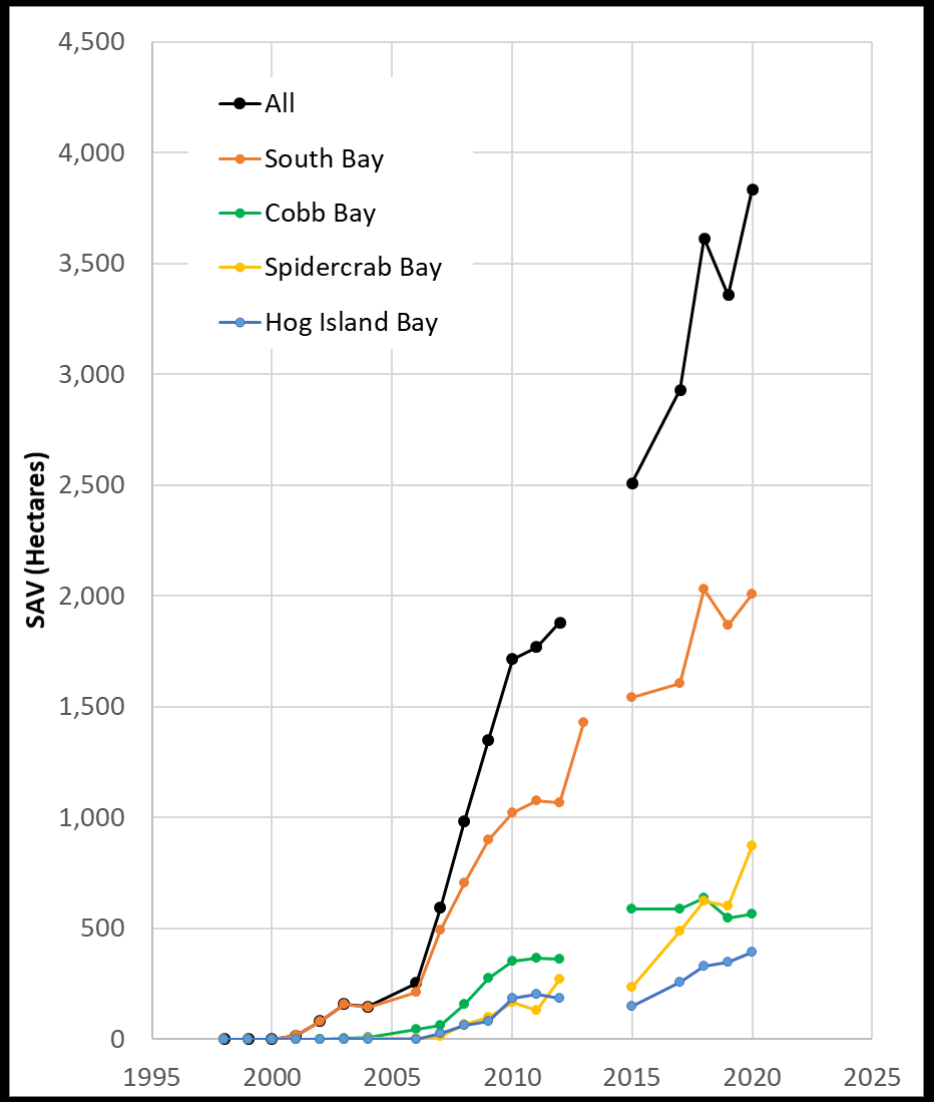

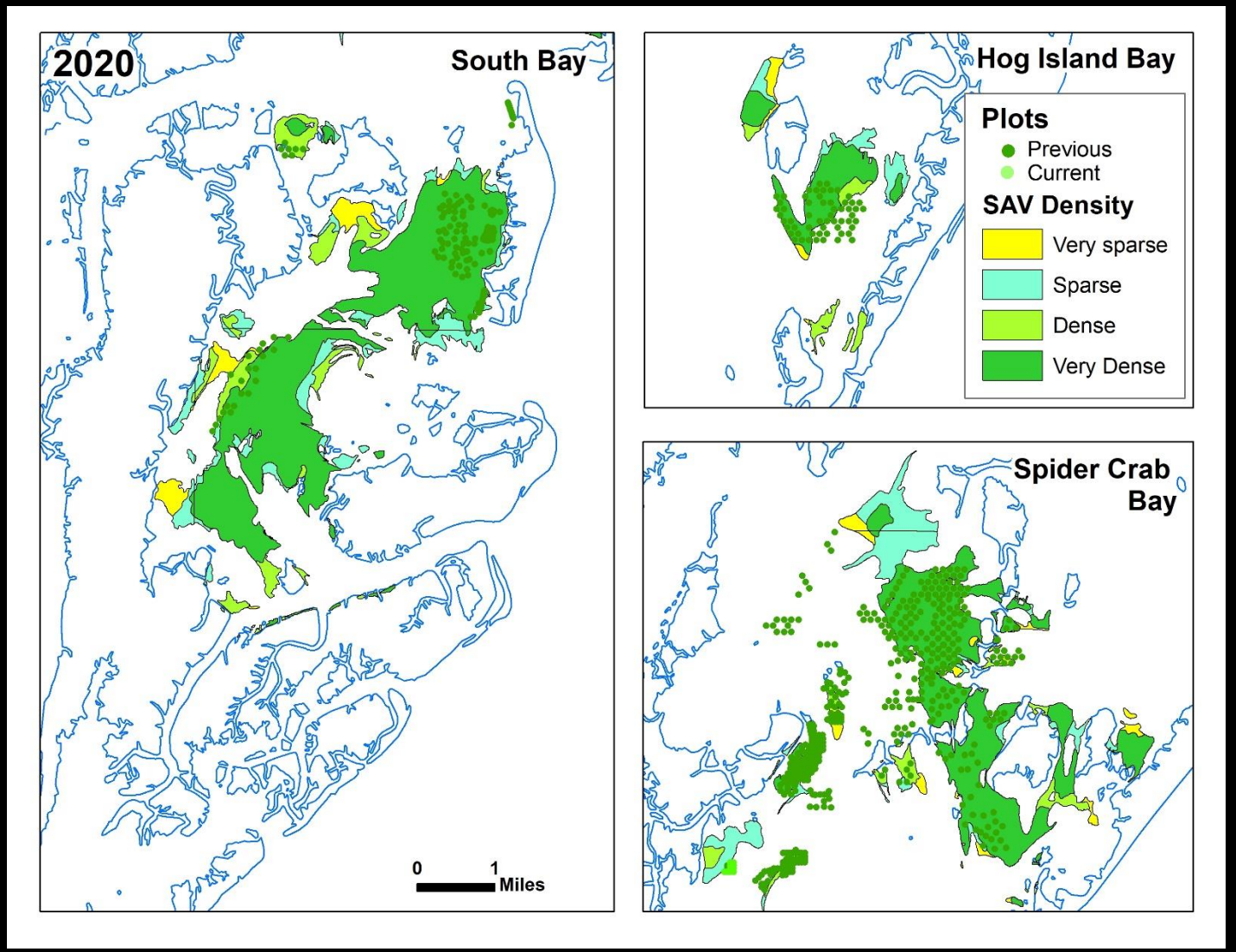

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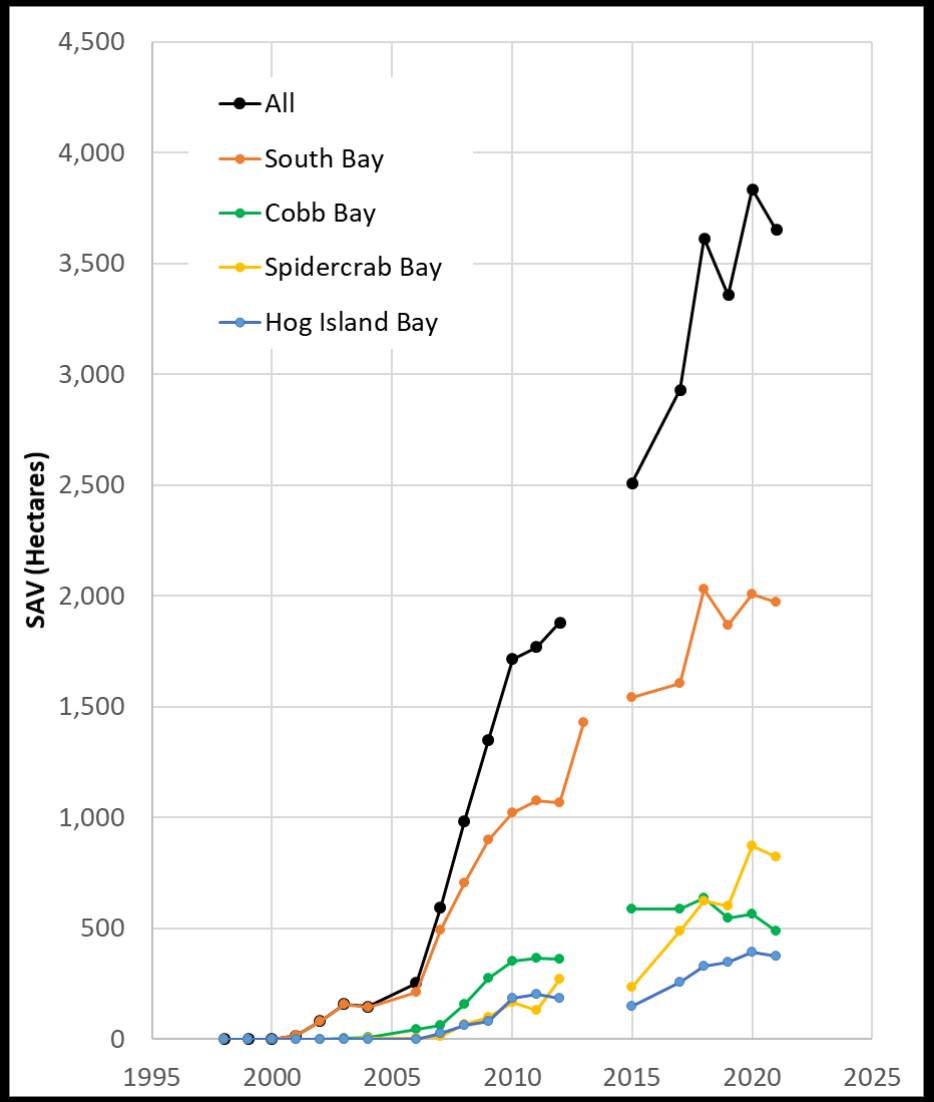

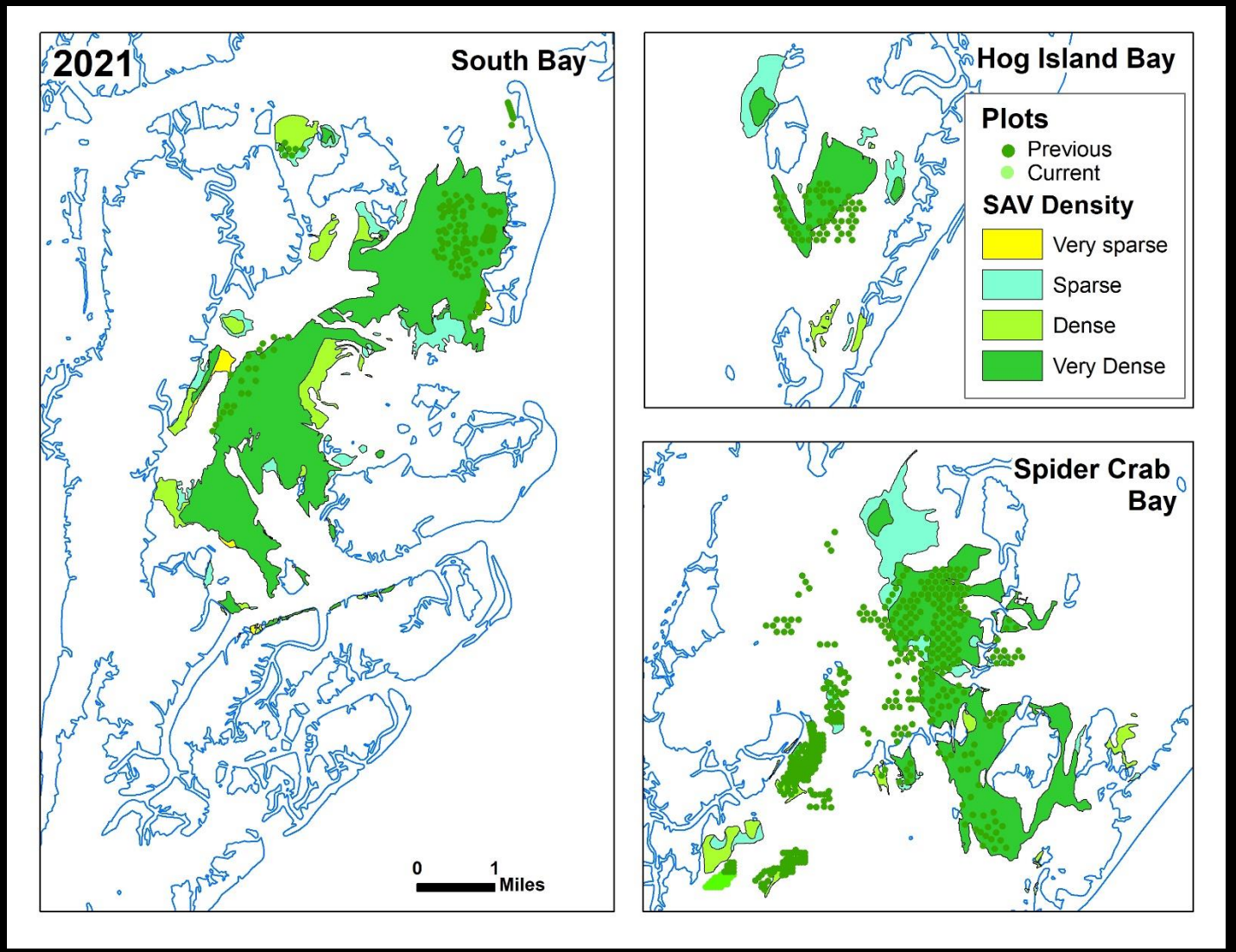

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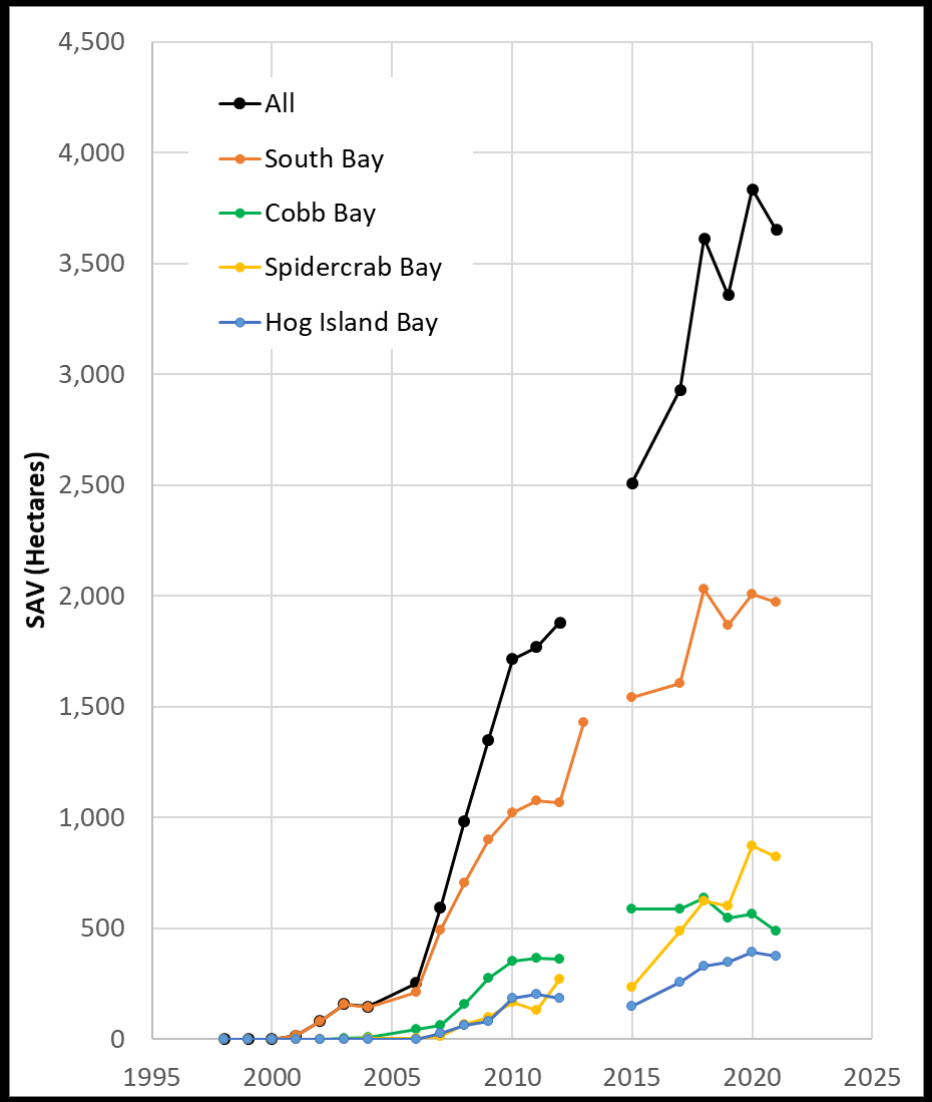

This is the most successful seagrass restoration on the planet.

Demonstrates amazing potential for rapid recovery of seagrass in years not decades to centuries.

Cost effective: ~ 15 acres for every acre planted

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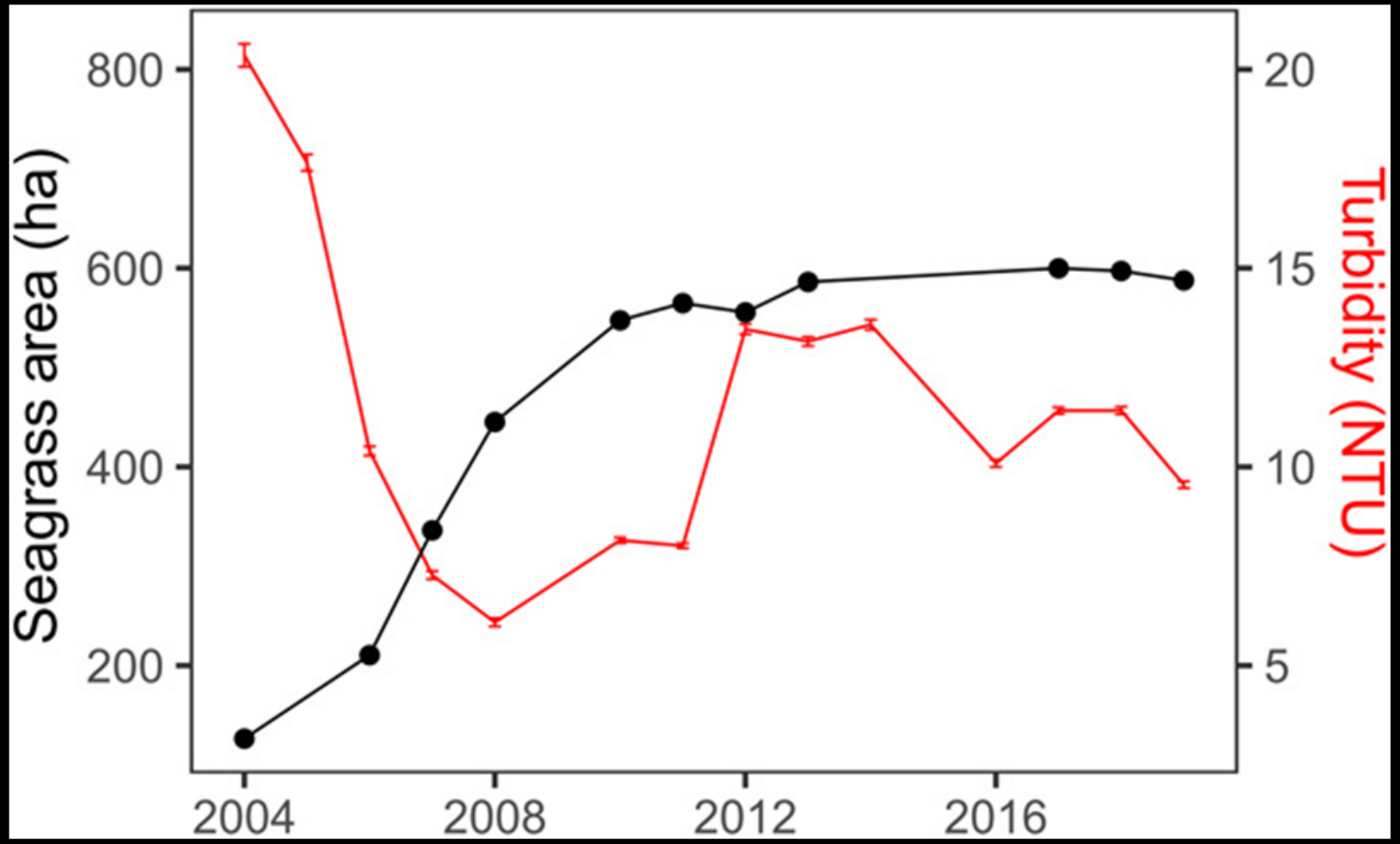
What we're doing about it: The benefits

As the restored seagrass meadows in South Bay expanded, turbidity in the meadow dropped precipitously

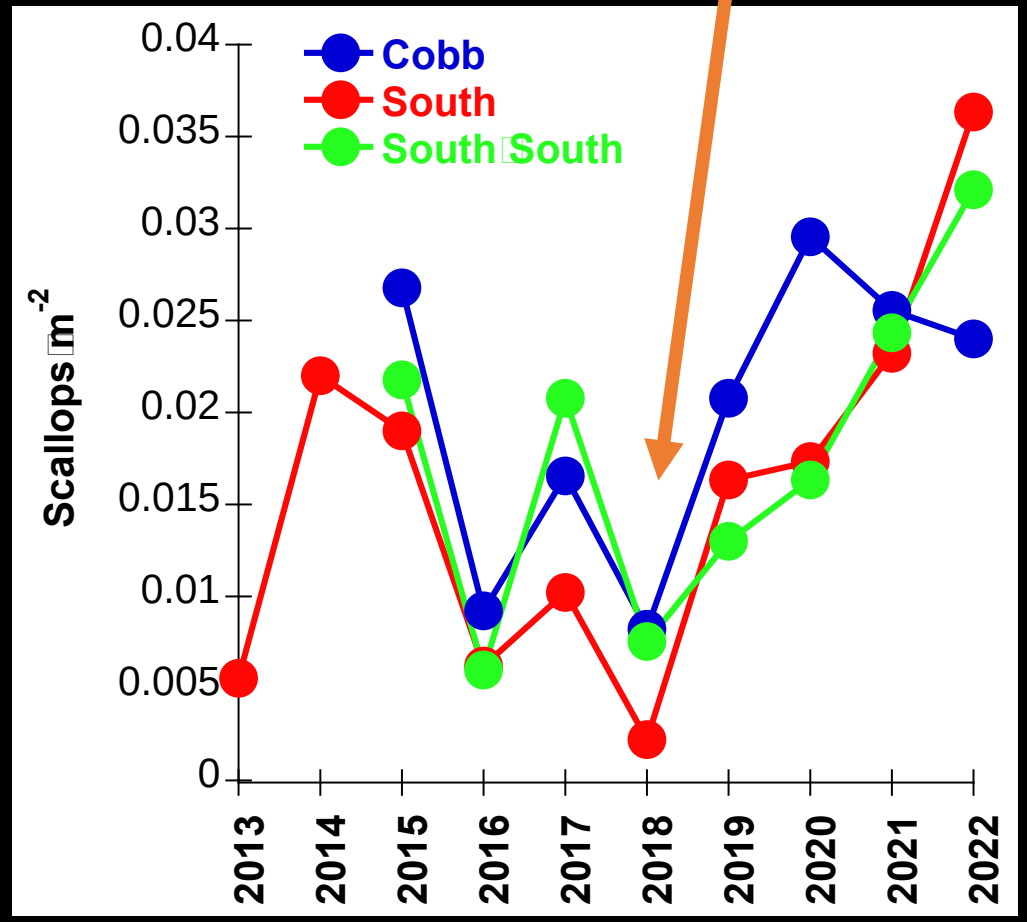


Orth et al. 2020

Clearer water as a result of the restoration!

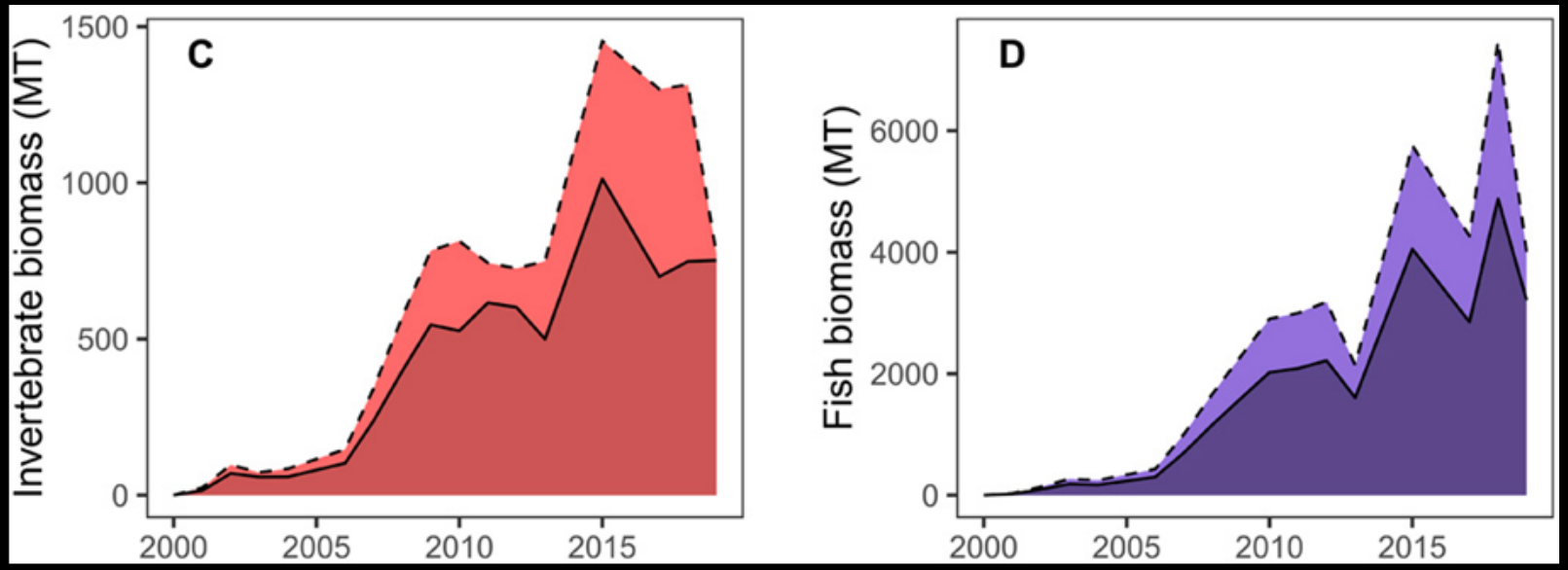
What we're doing about it: The benefits

New Genetic lines added



~ 1.1 million scallops in the meadows

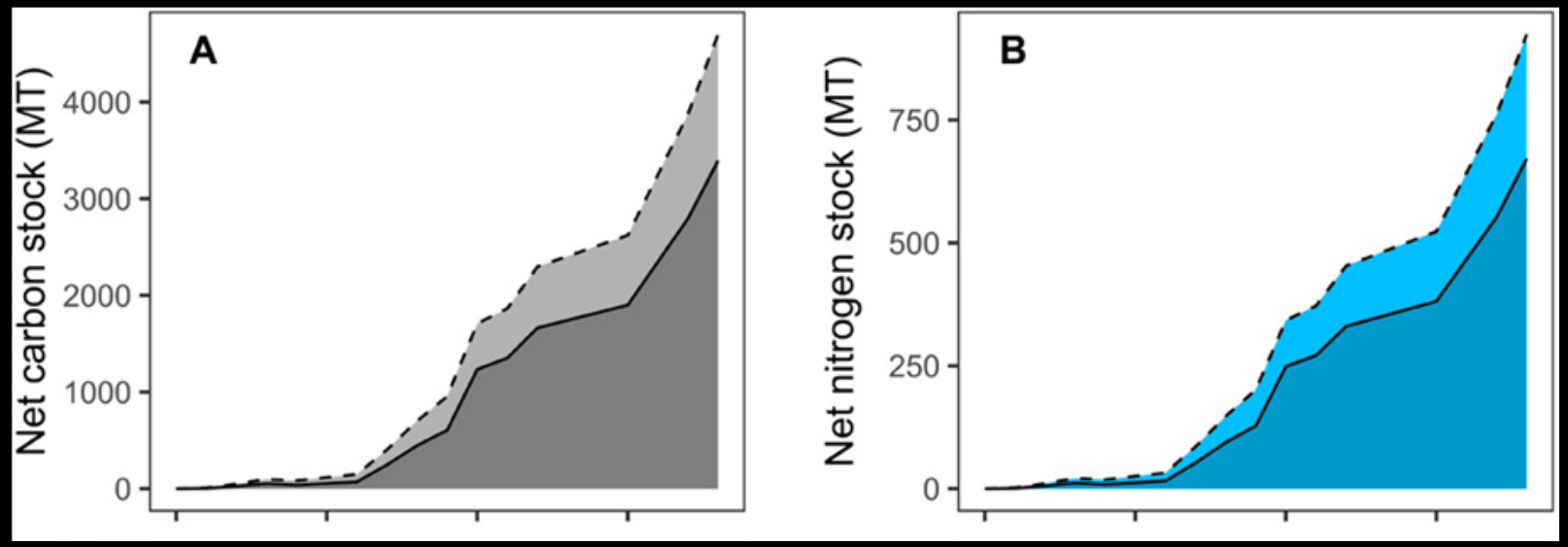
What we're doing about it: The benefits



Huge increases in the abundance of invertebrates and fish living in the bays as well as waterfowl such as Brant.

Orth et al. 2020

What we're doing about it: The benefits



Thousands of tons of blue carbon and nitrogen sequestered by the meadows and more capture each year!

First accredited blue carbon market for seagrass in the world.

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University of Virginia 1819

TerraCarbon®

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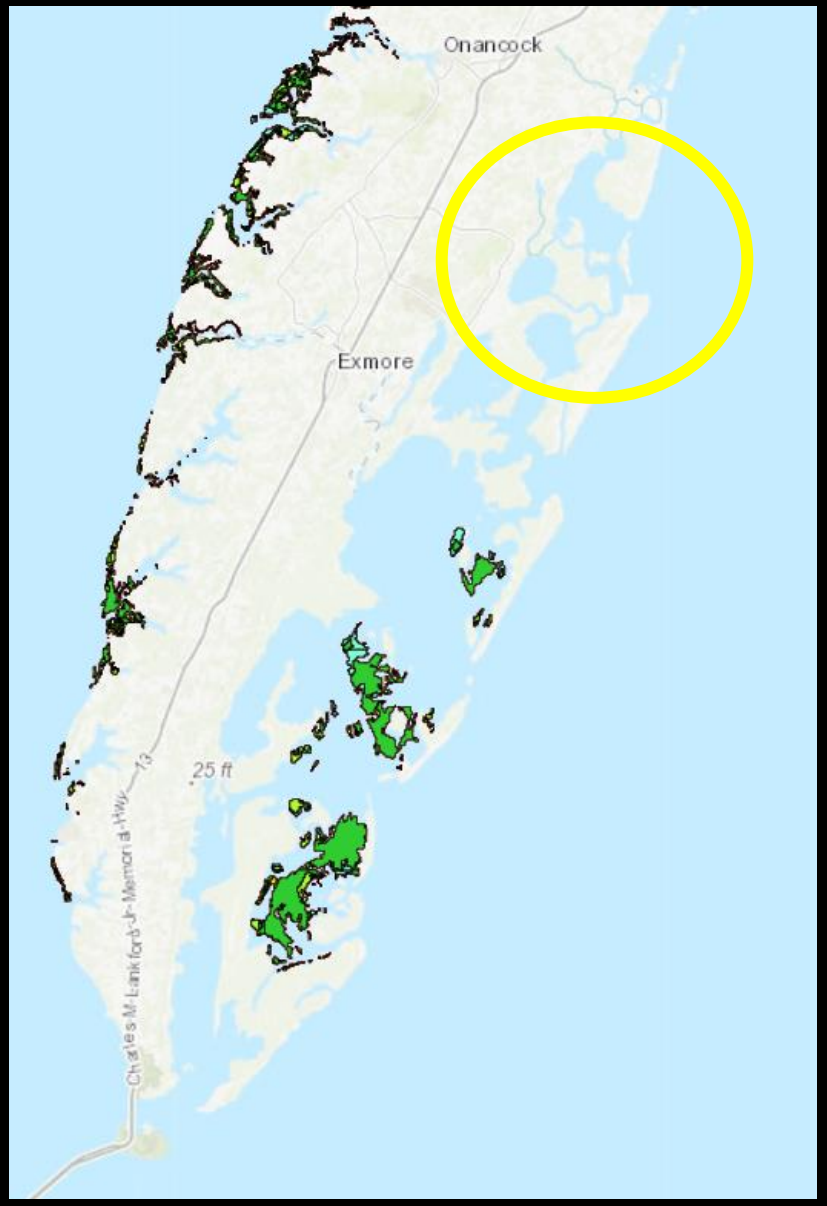
What we're doing about it: Next Steps BIL



Middle VA Seaside is isolated

- ***Burtons Bay, Bradford Bay, Swash Bay***

Our goal is to restore eelgrass, bay scallops, and associated functions to these northern bays and monitor the effects of the restoration

<u>NOAA BIL Funding</u> is making it possible to bring this program to another bay system and do it again!

What we're doing about it: Next Steps BIL

Mary Fabrizio,
VIMS

Chris Patrick,
VIMS

Richard Snyder,
VIMS - ESL

Bowdin Lusk,
TNC

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University of Maryland
Center for Environmental Science

Jan McDowell,
VIMS

Troy Tuckey,
VIMS

Rob Latour,
VIMS

Hongsheng Bi,
UMCES

Virginia Coastal Zone
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What we're doing about it: Progress

- In April/May 2023 VIMS and TNC collected ~ 10 million Zostera Seeds

What we're doing about it: Progress

- Notes on methods:
  - Seed Harvester vs. Hand Collection

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- Notes on methods:
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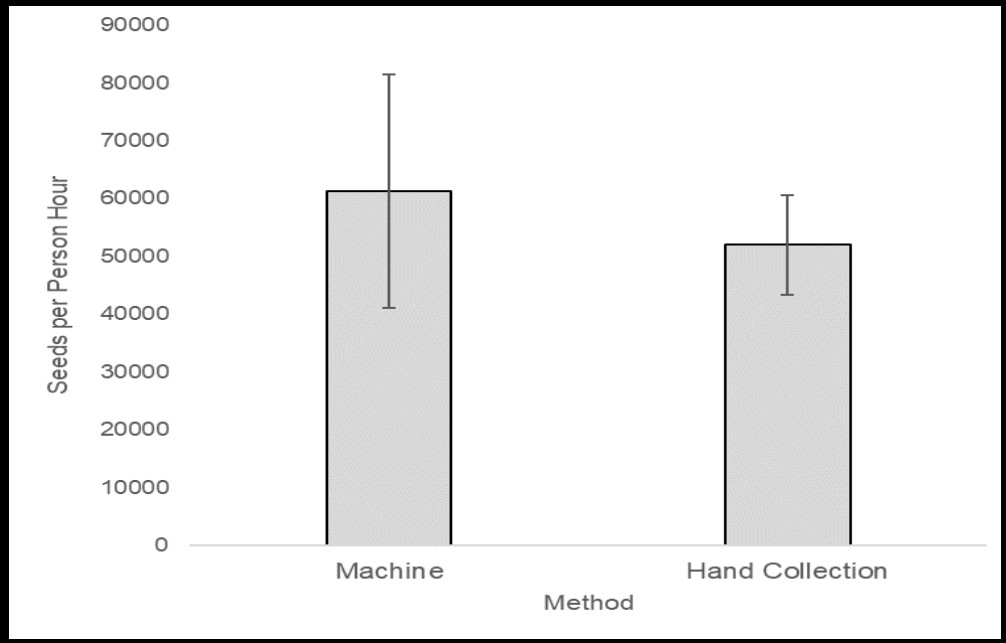
What we're doing about it: Progress

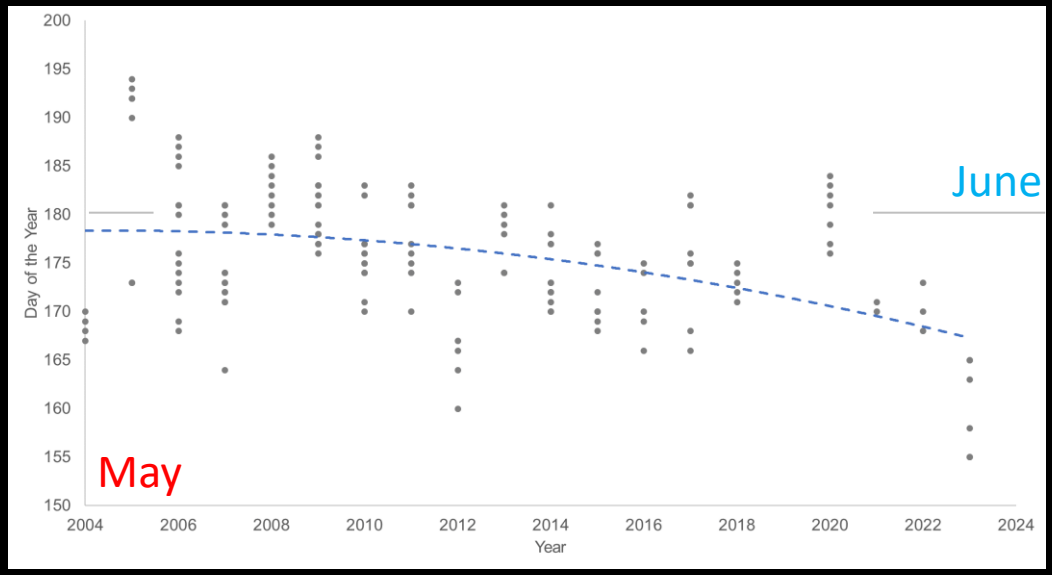
- Notes on methods:
  - Seed Harvester vs. Hand Collection
  - Update: Hand collection by trained personnel has been found to be the most effective method per unit effort in our shallow water bays.
  - Seed harvester may be better option in deep waters where SCUBA needed



What we're doing about it: Progress

- Notes on methods:
  - Timing is critical!
  - We visit beds frequently through April and May to identify which donor beds are most productive that year and to time collections based on seed status
  - Too early can lead to larger proportion of non-viable seeds
  - A day or two too late can result in missing the harvest

Harvest date is trending earlier each year, climate change effect.



What we're doing about it: Progress

- Reproductive shoots with seeds transported to SAV Program at VIMS

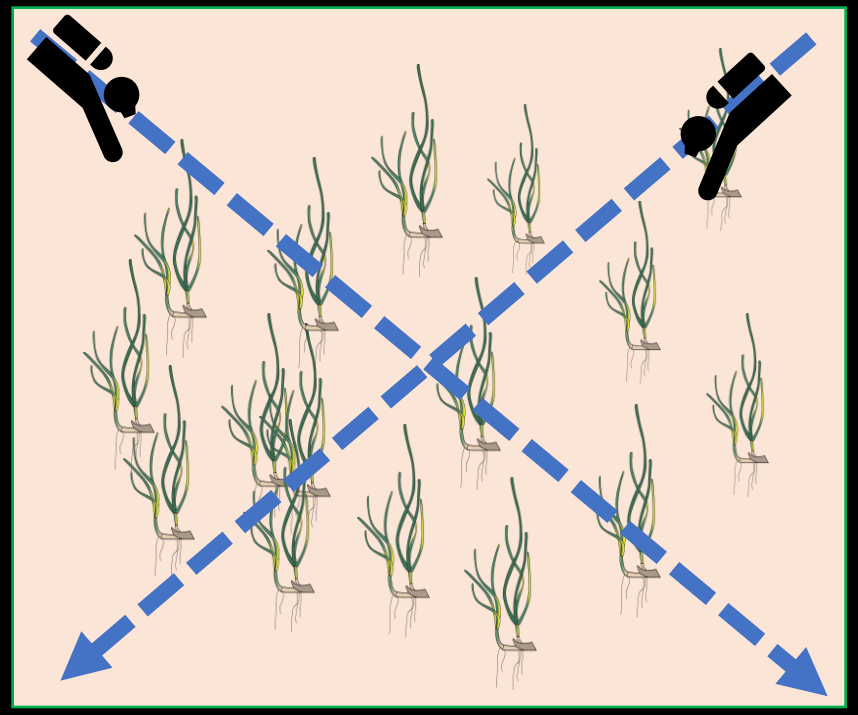
What we're doing about it: Progress

- Shoots volumetrically measured and held in tanks until seeds are released

What we're doing about it: Progress

- Seed separated from organics, assessed for quality (squeeze and drop tests) twice (Summer, Fall), held in warm (23°C) oxygenated water, and disbursed into planting sites in October (before germination, after seed predators are mostly gone)

What we're doing about it: Progress

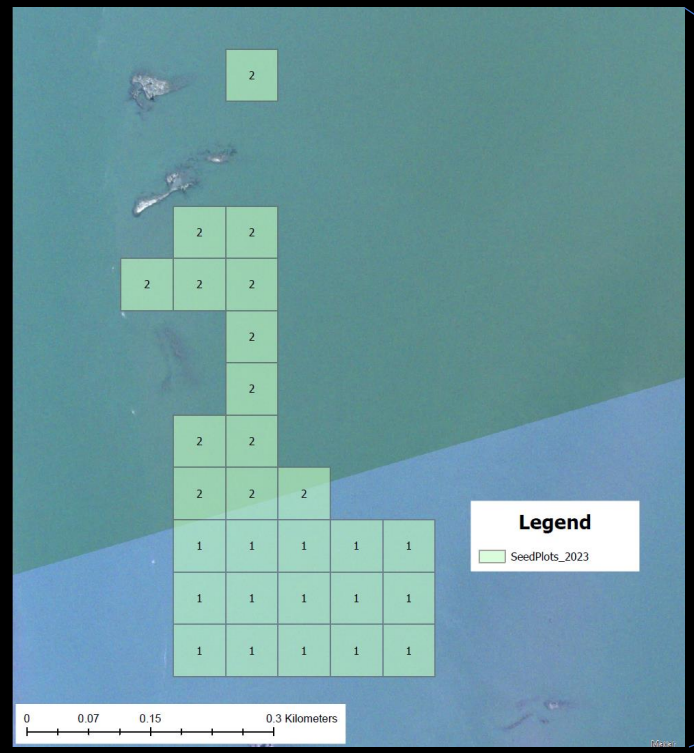


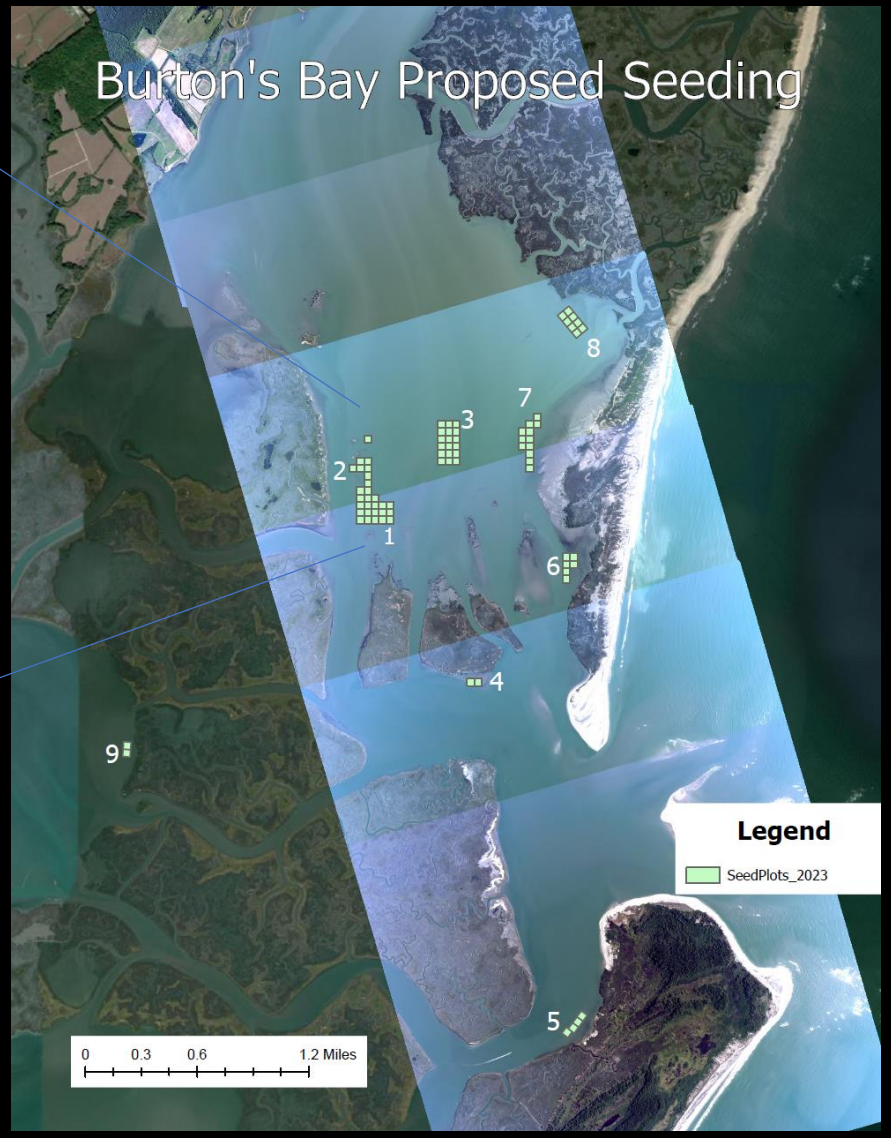
- Assessments occur in the field and lab
- Lab germination study to assess % good seed germination (usually 70-90%)
- Field assessment in April to count seedlings (5% OK, 20% great!)

What we're doing about it: Progress

In October 2023 we planted 80 acres of eelgrass in Burtons Bay

A program record!





What we're doing about it: Monitoring

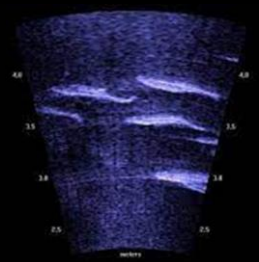
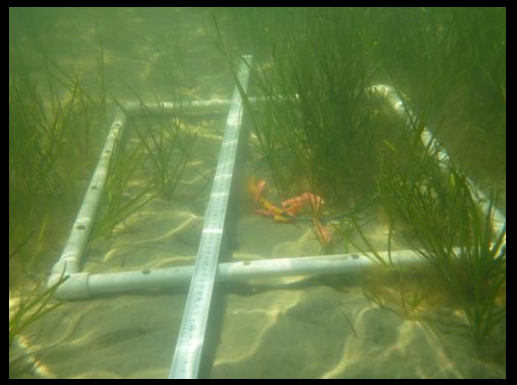
Over the next four years we'll be continuing the restoration, releasing 6 million scallops, and collected a comprehensive suite of information on:

Nekton and Large Predator Response
Water Quality Responses
Fish Movement
Infauna
Epifauna
Seagrass Responses
Sediment Responses (Carbon)
System Productivity
Biofilms
Scallop Responses and Genetics









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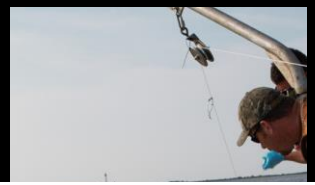
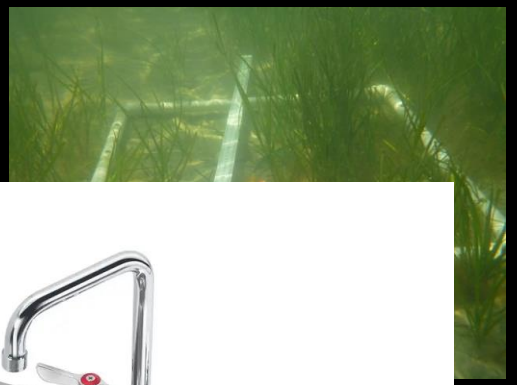
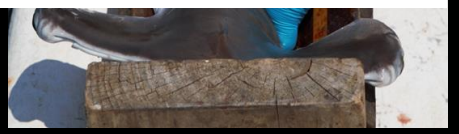


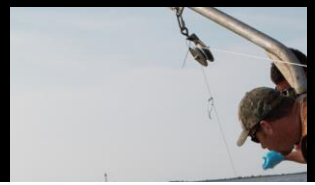
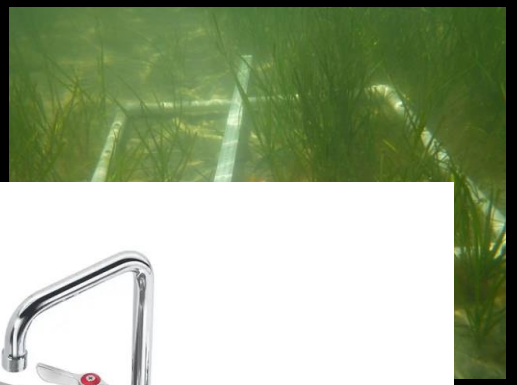




What we're doing about it: Outcomes

Unique opportunity to enact a whole system restoration and closely monitor the effects.

Invaluable opportunity to advance our understanding of the functional value of seagrass!

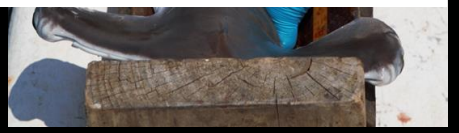







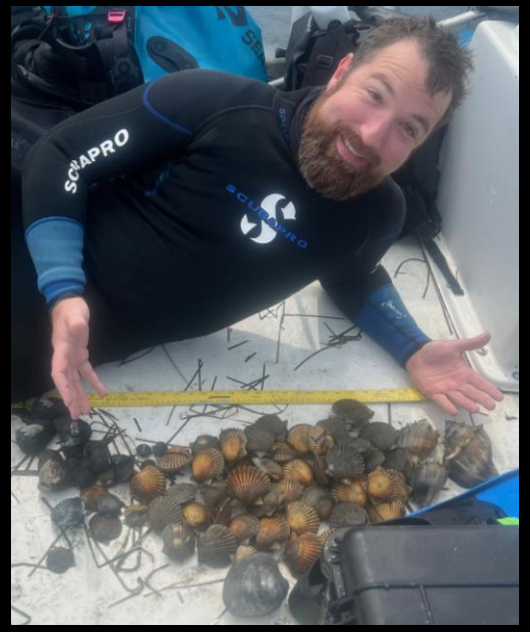






What we're doing about it: Outreach

We have been working with local watermen to educate them about the project and communicate benefits



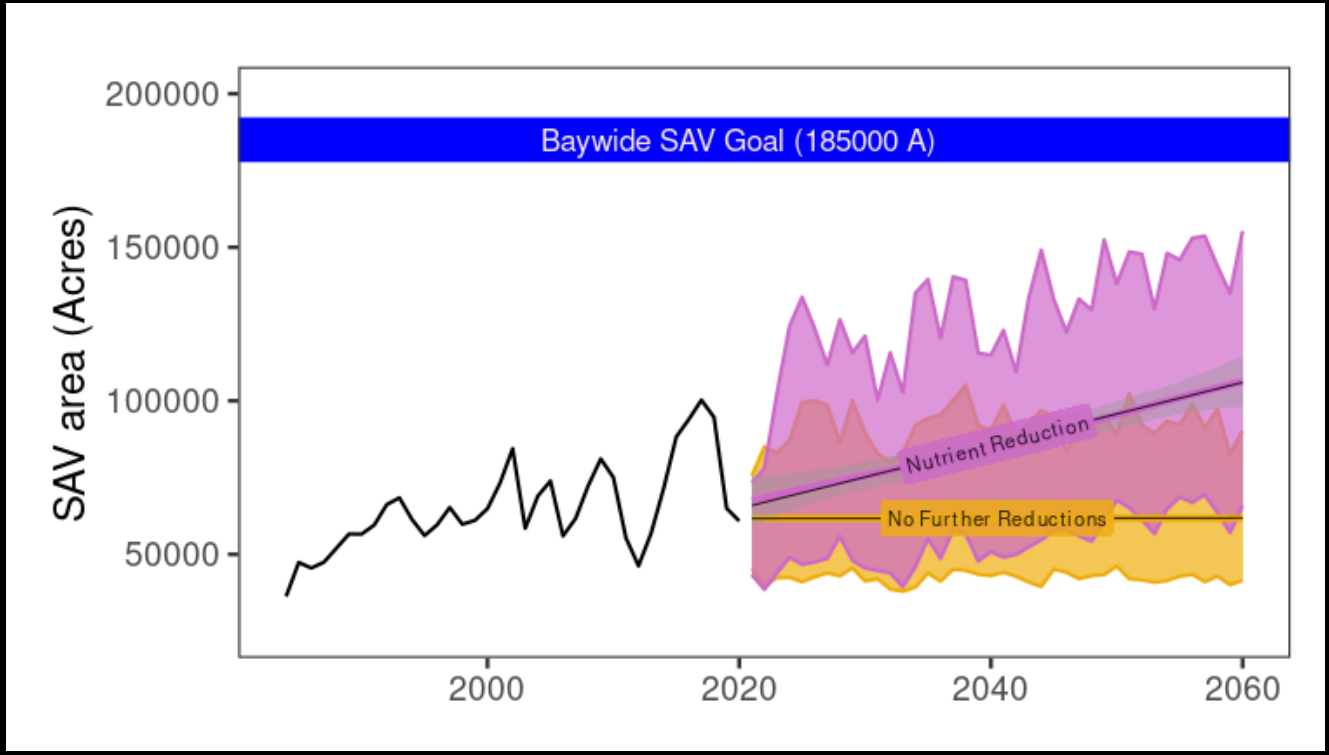
Critical Lessons from the Seaside Restoration

1) Seagrass can recover rapidly, here we see a 15:1 return on investment and 9000 acres in 20 years
   - *Other examples include Texas Laguna Madre, 160,000 acres in 20 years*
   - *One of the fastest marine biogenic habitat to restore at scale*
2) Habitat quality is critically important
   - Coastal bays have great water quality
   - Similar efforts in the Chesapeake have not been so successful
3) Seed based restoration, when it works, is more cost effective for large scale planting than transplants or similar methods

Take home

"Losing the possibility of something is the exact same thing as losing hope and without hope nothing can survive."
- Mark Danielewski, *House of Leaves*

There remains the possibility of a bright future for seagrass in our region.



https://www.vims.edu/research/units/programs/sav/predicting-sav/index.php

Take home

"*Losing the possibility of something is the exact same thing as losing hope and without hope nothing can survive.*"
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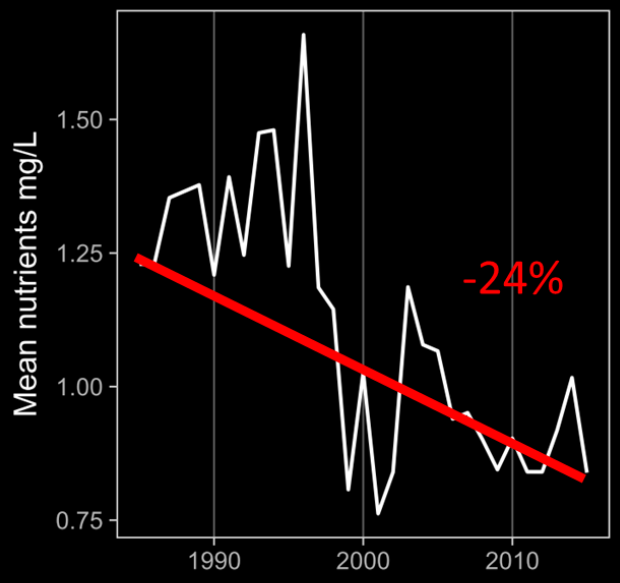
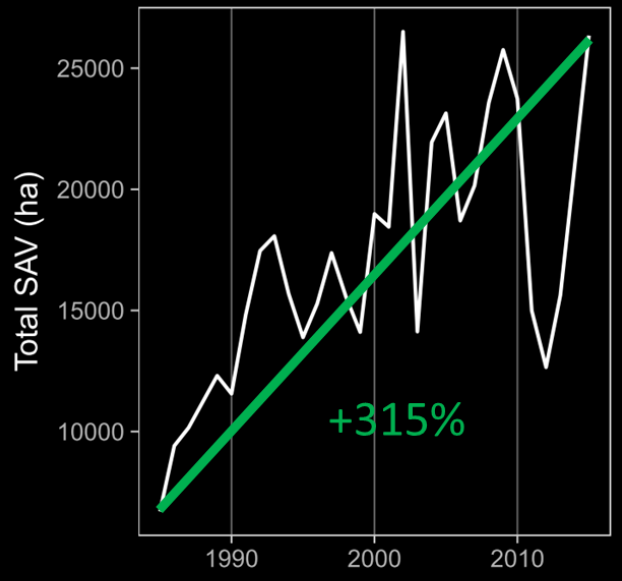
Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region

Jonathan S. Lefcheck[a,b,1], Robert J. Orth[b], William C. Dennison[c], David J. Wilcox[b], Rebecca R. Murphy[d], Jennifer Keisman[e], Cassie Gurbisz[f,g], Michael Hannam[h], J. Brooke Landry[i], Kenneth A. Moore[b], Christopher J. Patrick[j], Jeremy Testa[k], Donald E. Weller[h], and Richard A. Batiuk[l]





There remains the possibility of a bright future for seagrass in our region.

Water quality enhancements in Chesapeake Bay and elsewhere in the United States are benefiting SAV.

Take home

"*Losing the possibility of something is the exact same thing as losing hope and without hope nothing can survive.*"
- Mark Danielewski, *House of Leaves*

There remains the possibility of a bright future for seagrass in our region.

Water quality enhancements in Chesapeake Bay and elsewhere in the United States are benefiting SAV.

We have the tools to restore seagrass

In combination, we can ensure the continuation of the seagrass of our region in a changing world.

Acknowledgments

Huge thank you to the VIMS Mapping Team for GIS support, the Coastal & Estuarine Ecology Lab, and to the hundreds of volunteers who collected SAV species information over the last 36 years!

cpatrick@vims.edu https://www.vims.edu/research/units/labgroups/ceel/index.php

CEEL Coastal Estuarine Ecology Lab

Co-authors and Collaborators: Marc Hensel, Enie Hensel, Bowdin Lusk, Donald E. Weller, Michael Hannam, J.J. Orth, Dave Wilcox, Bill Dennison, Cassie Gurbisz, Jon Lefcheck, Becky Goldman, Brooke Landry, Richard Snyder, Mary Fabrizio, Troy Tuckey, Hongshen Bi, Robert Latour, James Gartland, Jan McDowell, P.G. Ross.

VIMS | William & Mary
Virginia Institute of Marine Science

Maryland Department of Natural Resources

Virginia Coastal Zone Management Program

Chesapeake Bay Program
A Watershed Partnership

National Oceanic and Atmospheric Administration
NOAA
U.S. Department of Commerce

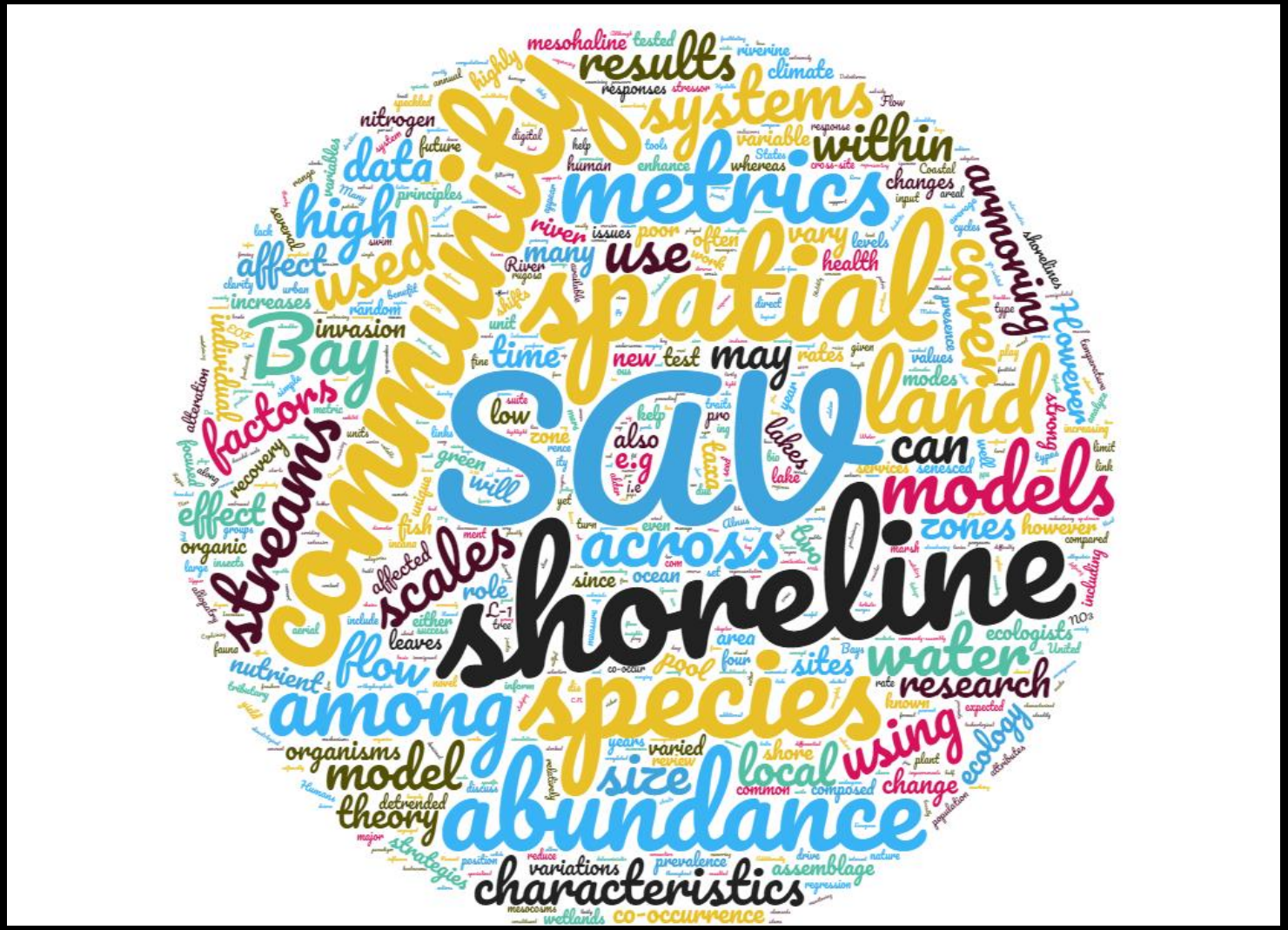
Maryland Department of the Environment

Innovation for a better future
University of Maryland
Center for Environmental Science

United States Environmental Protection Agency

Virginia Marine Resources Commission

Questions? Want to come for a site visit??



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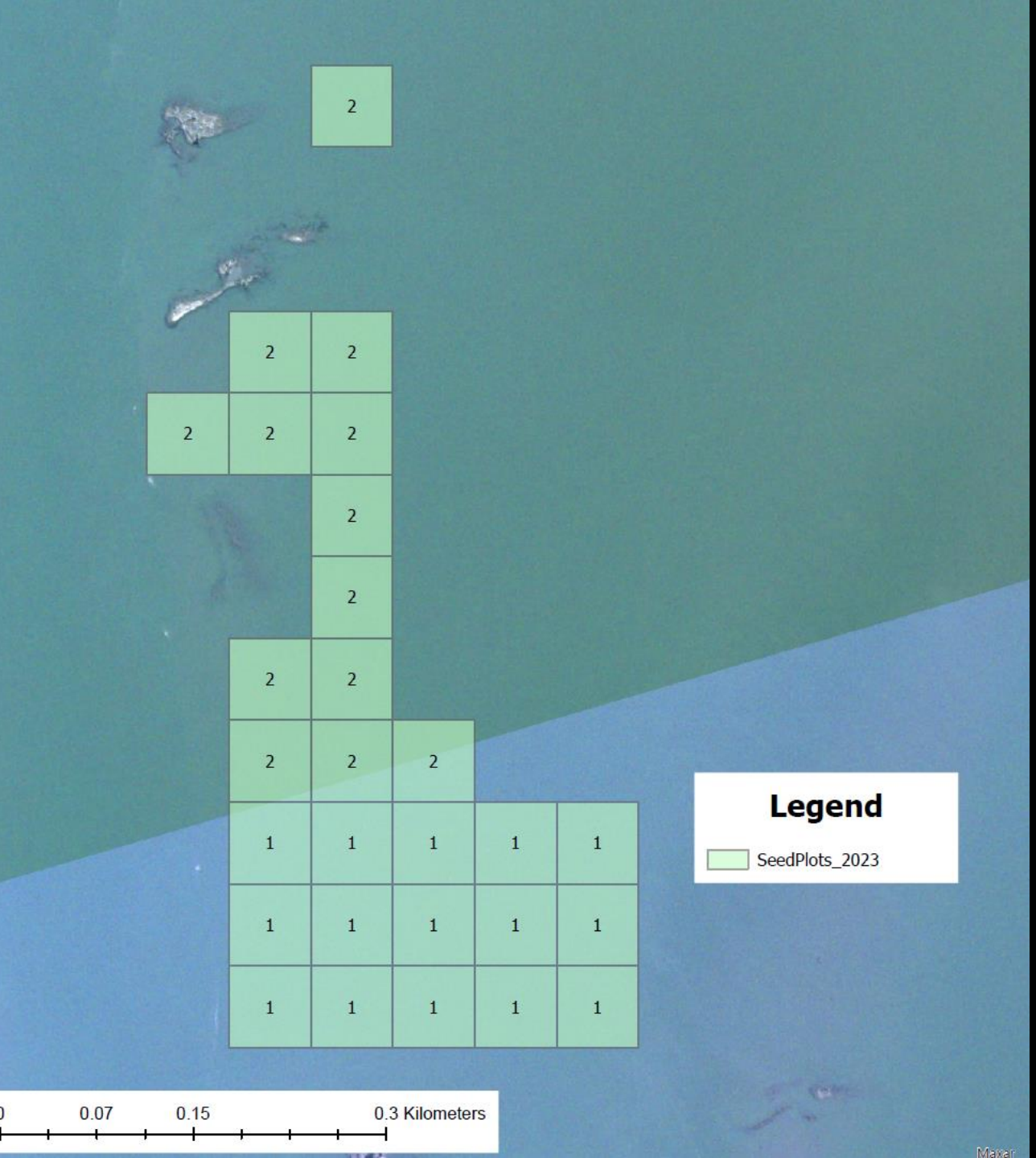
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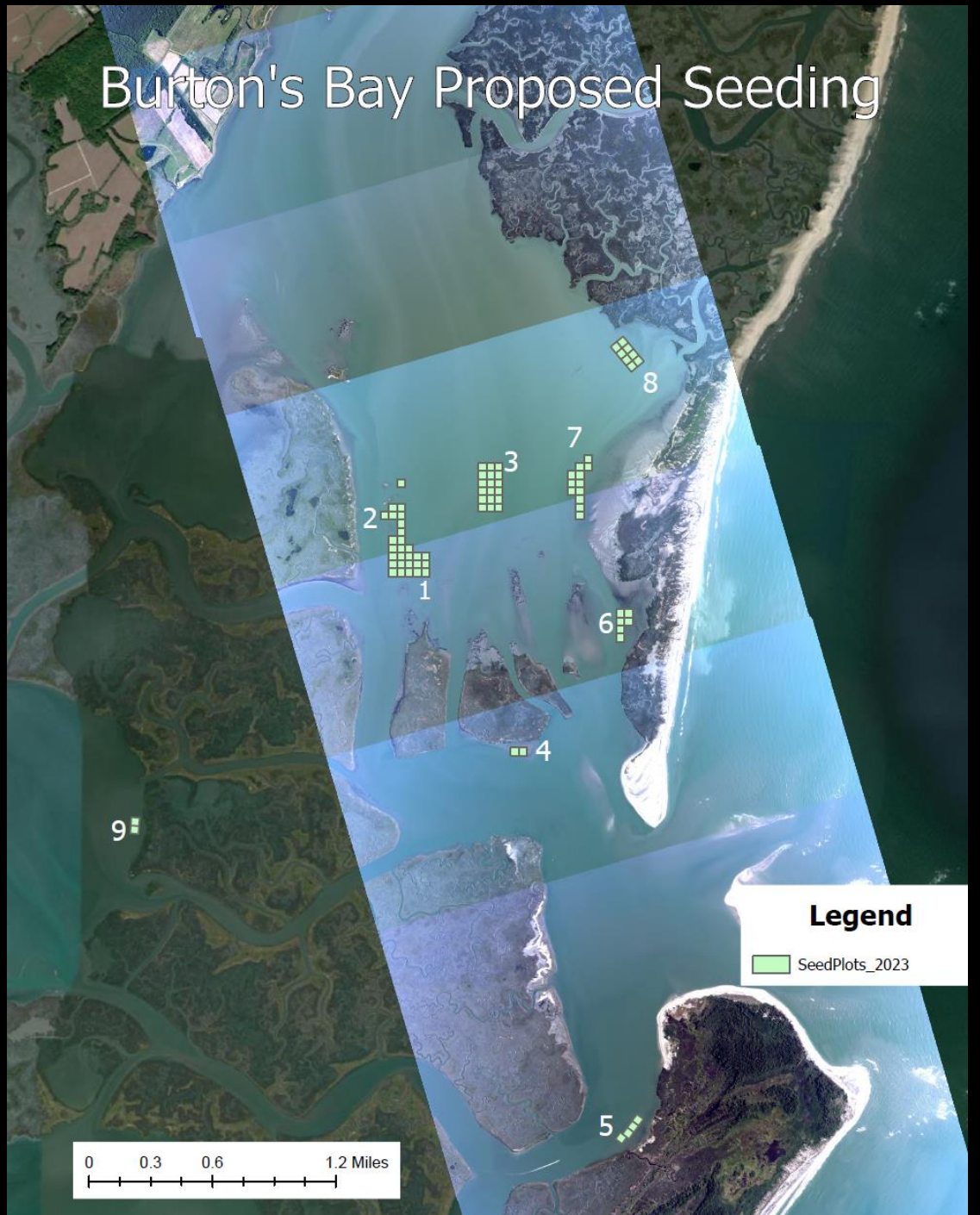
Burton's Bay Proposed Seeding
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Legend
SeedPlots_2023
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0.3
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1.2 Miles


DO IT
RIGHT
LOWE'S

What we're doing about it?

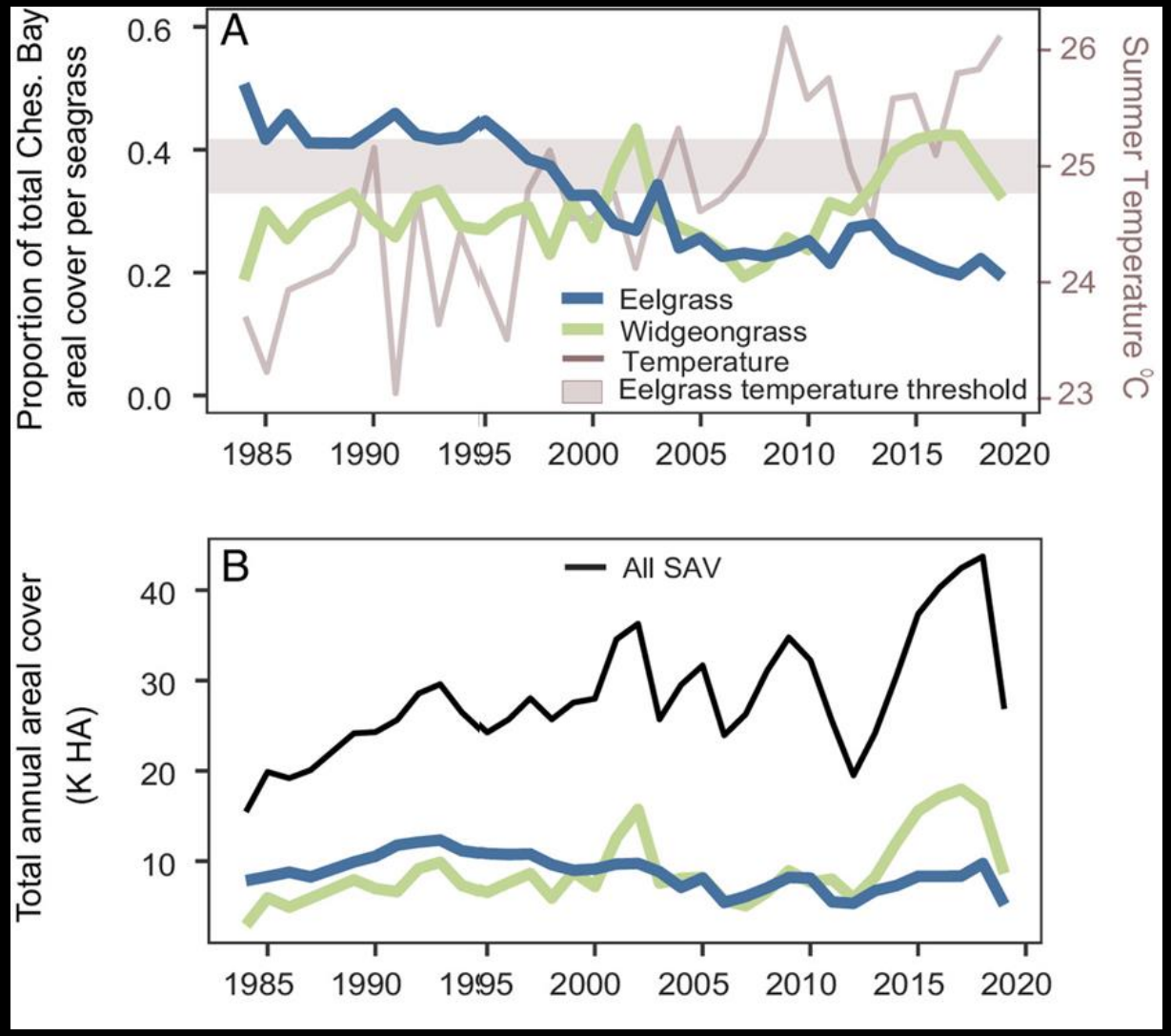
1) We can work to enhance water quality and light to support seagrass health!

2) In areas where conditions are appropriate for restoration, but the grass is absent, we can plant seagrasses.

3) In areas where there is a concern about future climate conditions:

i. Considering the potential for climate resilient seagrass species to be introduced from the south.
ii. Considering the potential to introduce more climate resilient genes into local populations.
iii. Considering the potential to enhance restoration success through use of climate resilient and locally present native species.

What we're doing about it: Climate Resilience



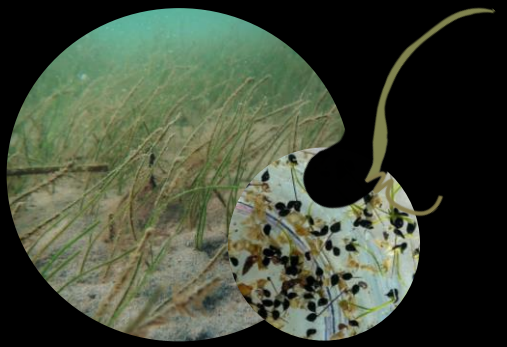
Hensel et al. 2023

In recent years it has become clear that widgeongrass (*Ruppia*) has become a major player in the new Chesapeake Bay and its influence will only increase as our climate warms.

Marc Hensel, Ph.D.

What we're doing about it: Climate Resilience

Shorter and less biomass than eelgrass, but tolerant to high temperatures with a hardy and long-lived seedbank.

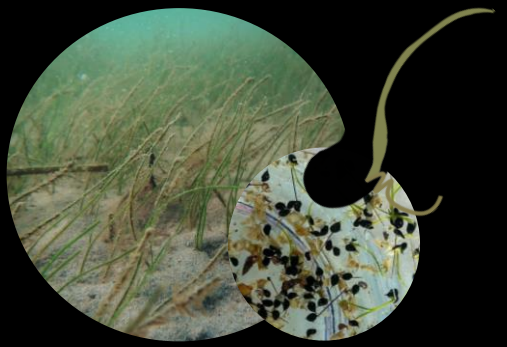


Zostera marina

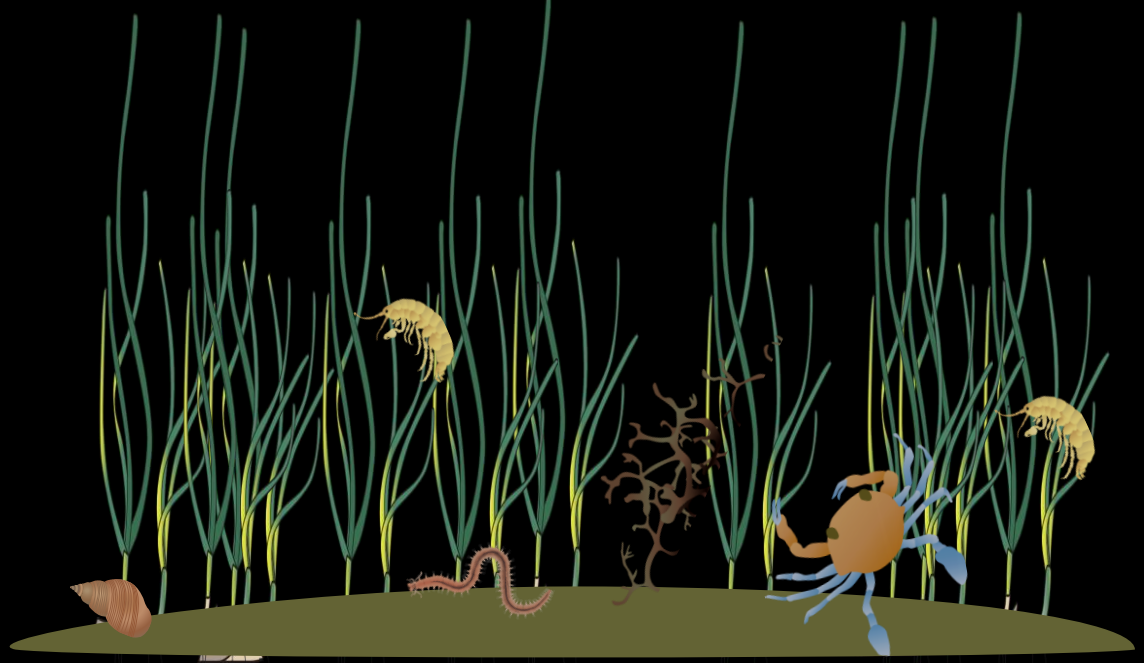
Ruppia maritima

What we're doing about it: Climate Resilience

Widgeongrass may help support Zostera and mixed species seagrass meadows may be more stable over time.



Zostera marina



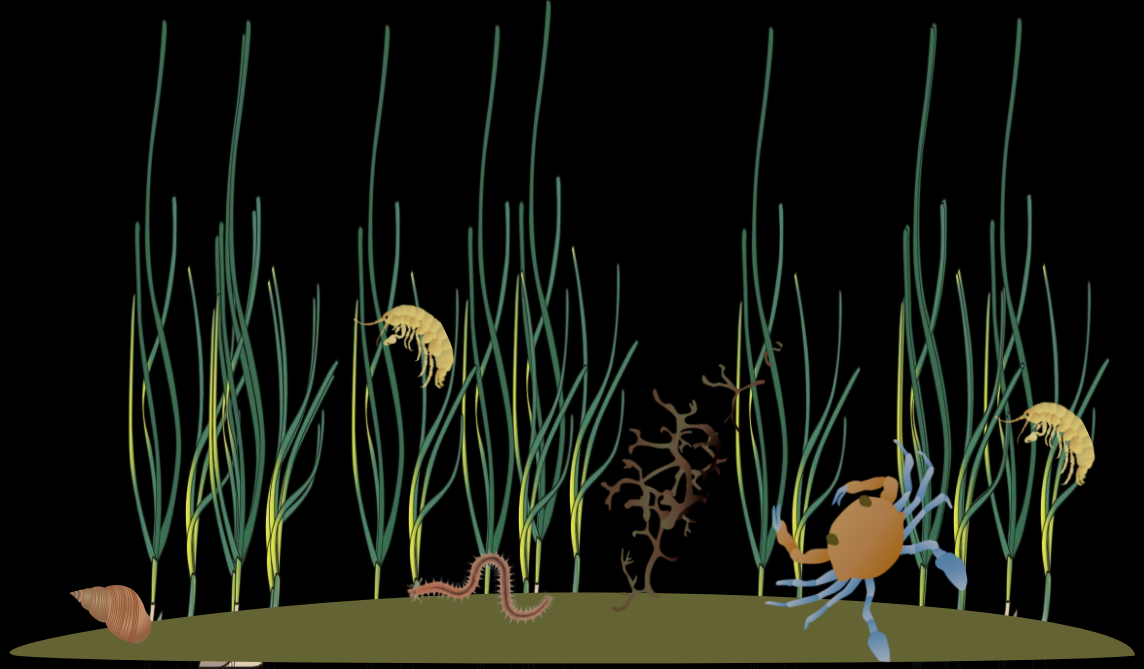
Ruppia maritima

What we're doing about it: Climate Resilience

Can we restore widgeongrass at scale?

What are the best practices for doing so?

Zostera marina



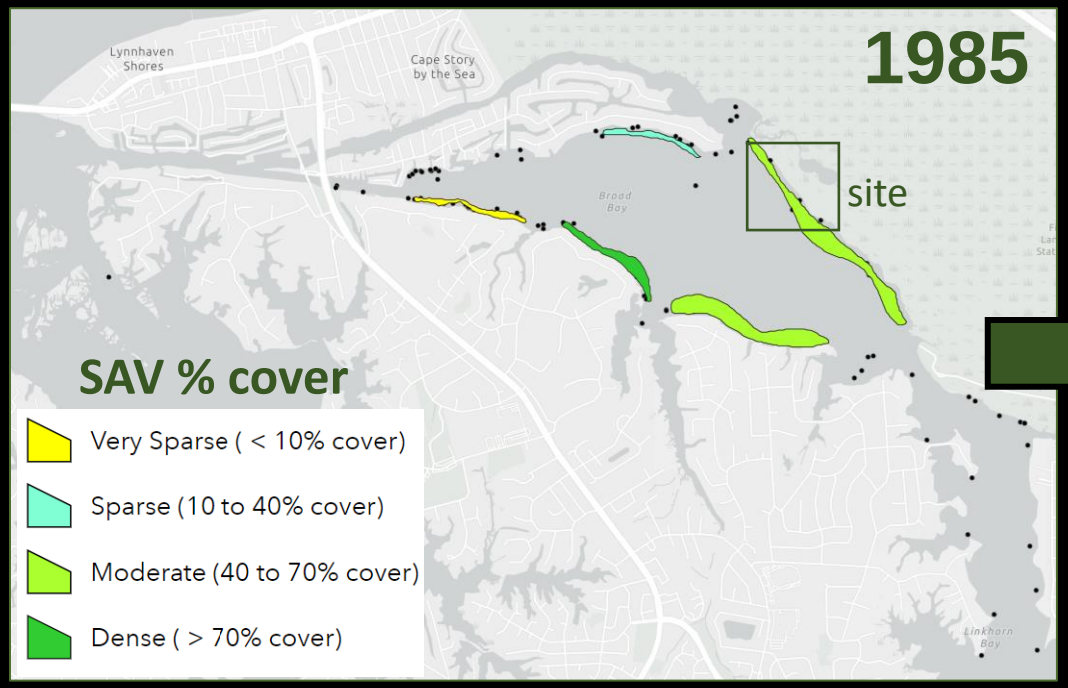
Ruppia maritima

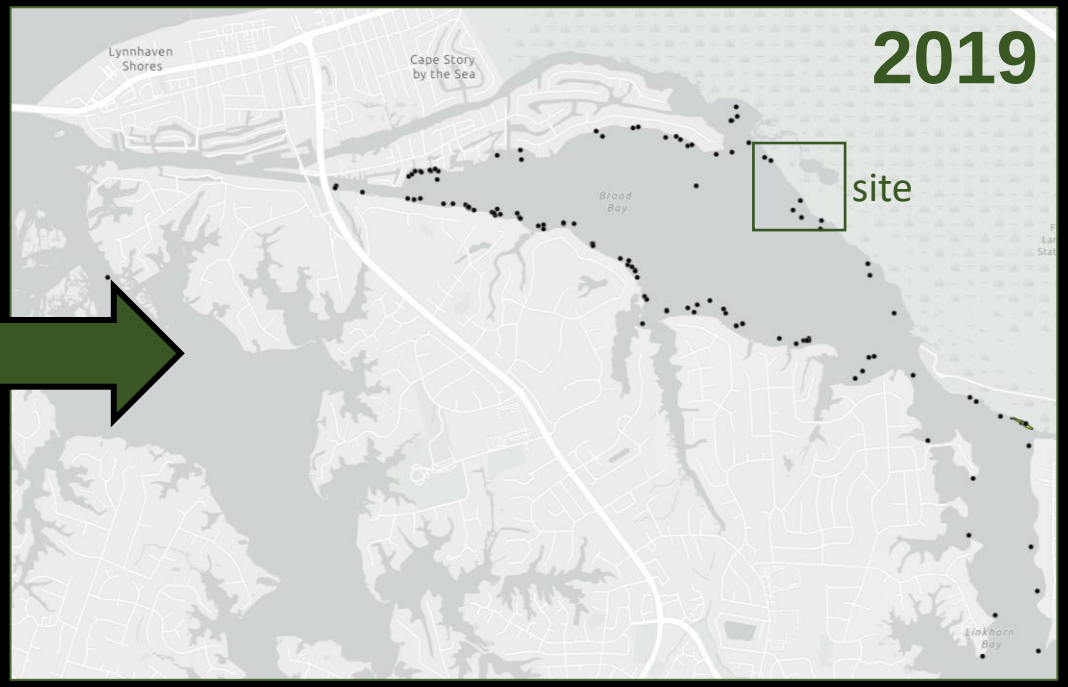
What we're doing about it: Climate Resilience

An example of developing successful practices for current & future conditions

Broad Bay SAV Decline

Submerged Aquatic Vegetation

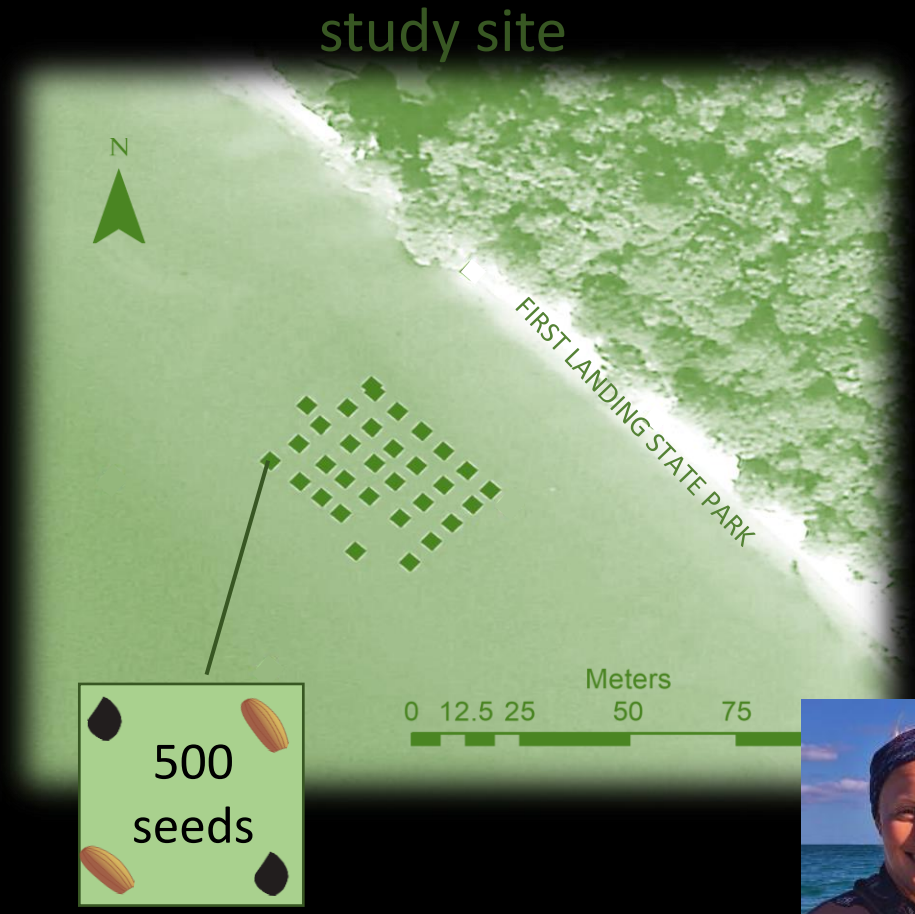




What we're doing about it: Climate Resilience

How best to restore widgeongrass?

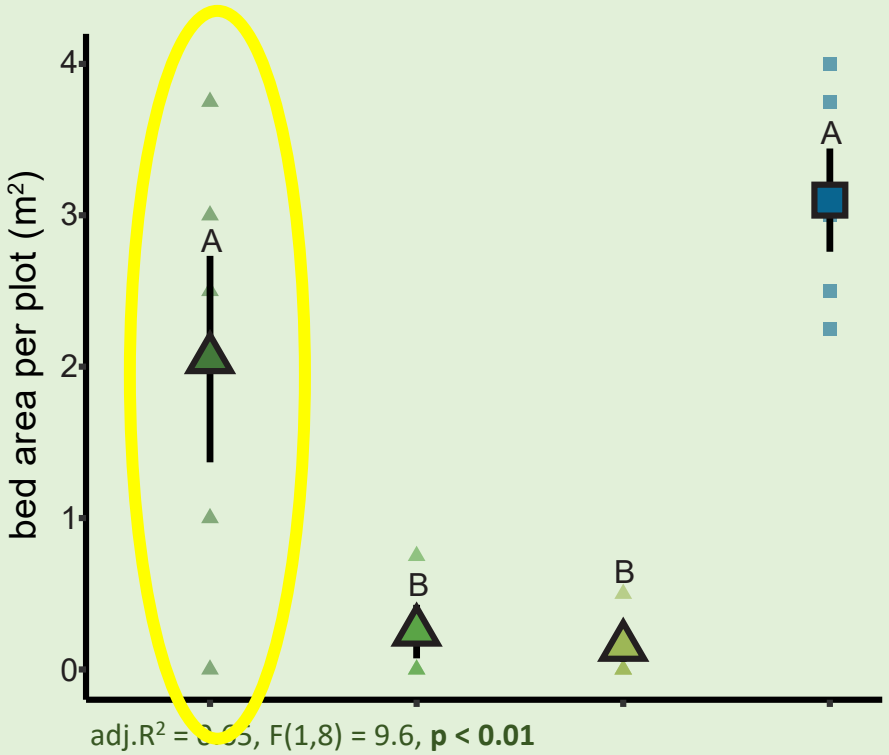
- ***Zostera maritima*** – seeded in fall
- ***Ruppia maritima*** – seeded in fall
- ***Ruppia maritima*** – seeded in spring
- ***Ruppia maritima*** – seeded in spring + freshwater shock
- **bare sediment control**

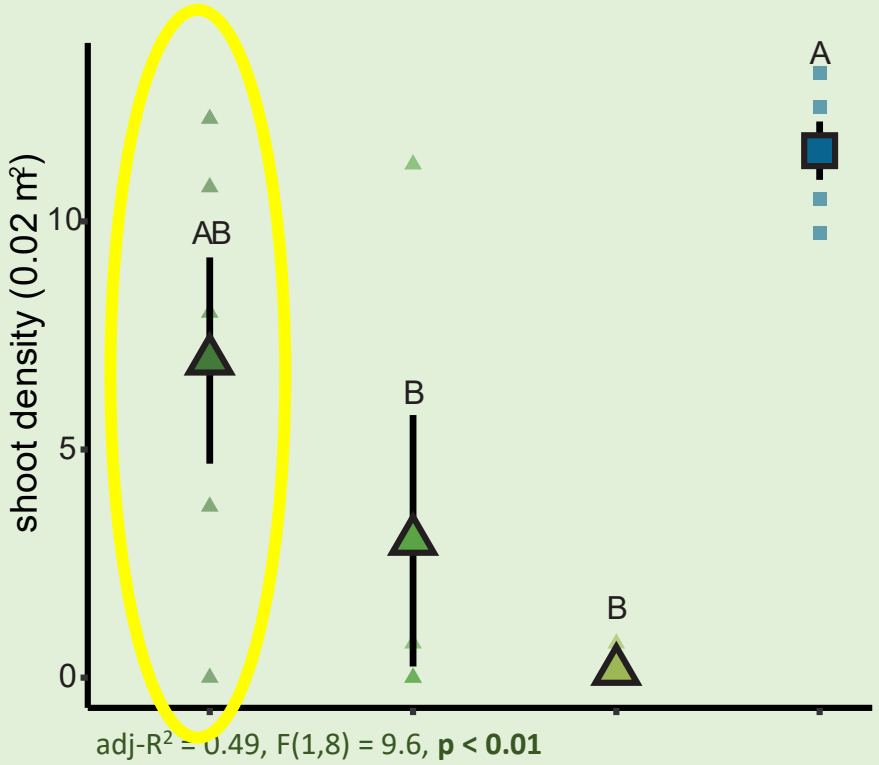


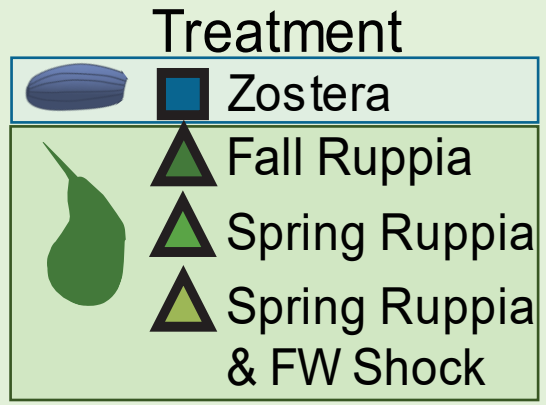
Ennie Hensel, Ph.D.

What we're doing about it: Climate Resilience

Zostera and fall seeded *Ruppia* established similar bed area and shoot density



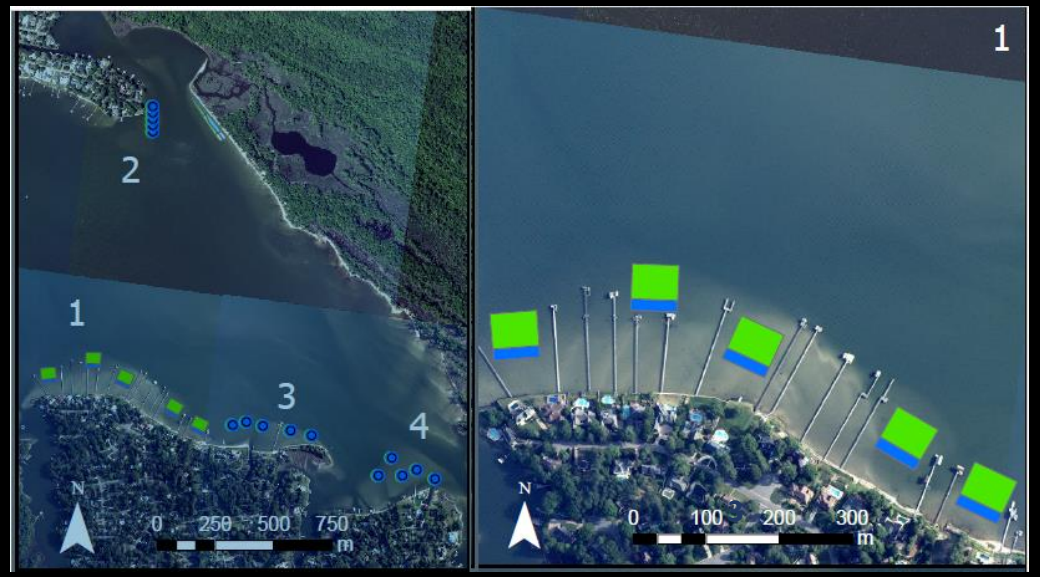




What we're doing about it: Climate Resilience

Planted Fall 2021, Image May 2022

A successful method for restoring Ruppia meadows alongside Zostera



Planted Fall 2022, additional plans for planting late fall 2023/winter 2024

Water quality concerns at the site may limit long term success, but the important point is the proof of concept. <u>We can restore *Ruppia* at large scales.</u>