National Park Service
Inventory & Monitoring Division

Evolution of the SET Data Lifecycle and Strategies for Integrating Research Into Natural Resource Management

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Outline

1. My background and current research focus
2. The SET data lifecycle
3. Research vs/and Monitoring
4. Common SET data issues
5. Fortifying the SET lifecycle
6. Tools for fortifying the SET lifecycle
7. Strategies and examples of integrating SET research into natural resource management
8. Tools for integrating SET research into natural resource management

1. Background

- **2007-2010**: BS Biology (Salisbury University) & BS Environmental/Marine Science (UMES)
- **2012-2015**: MS Biology (UL Lafayette)
- **2015-2024**: Ecologist, USGS Wetland and Aquatic Research Center (Lafayette LA)
- **2024-present**: Biologist, National Park Service, Inventory & Monitory Division, Northeast Coastal and Barrier Network (eastern shore MD)

Interests & Expertise:
coastal ecology, salt marshes, mangroves, environmental data science, data synthesis, effects of climate change on coastal ecosystems, wetland restoration

1. Background – My SET Experience

- USGS SETs in Everglades NP
  - Continued monitoring setup by Tom Smith in the 90s, now led by Mike Osland
  - Organized and QAQC'ed 20+ years of SET data
  - Osland et al. 2020, Feher et al. 2020, Breithaupt et al. 2020
- FWS SETs in coastal Texas
  - Organized, QAQC'ed, and analyzed SET data from 5 NWRs in coastal Texas
  - Moon et al. 2022
- South Florida SET synthesis
  - Integrated SET data from 14 partners – 122 SETs across 51 different sites
  - Developed R scripts for transformation and analysis
  - Feher et al. 2024a, Feher et al. 2024b
- NPS SETs along NE US coast
  - Organized + QAQC'ed 20+ years of SET data – 155 SETs across 9 parks setup by Jim Lynch
  - R package for data transformation, analysis, plotting
  - In progress: interactive data visualizers, additional publications, data packages

1. National Park Service Inventory & Monitoring Program

- Natural resource **inventories** help us understand the range of natural resources in and around parks.
- Long-term **monitoring** helps us understand how these resources may be changing over time.
- Detecting change, identifying any potential problems in the early stages, and measuring success.

Vital Signs Monitoring

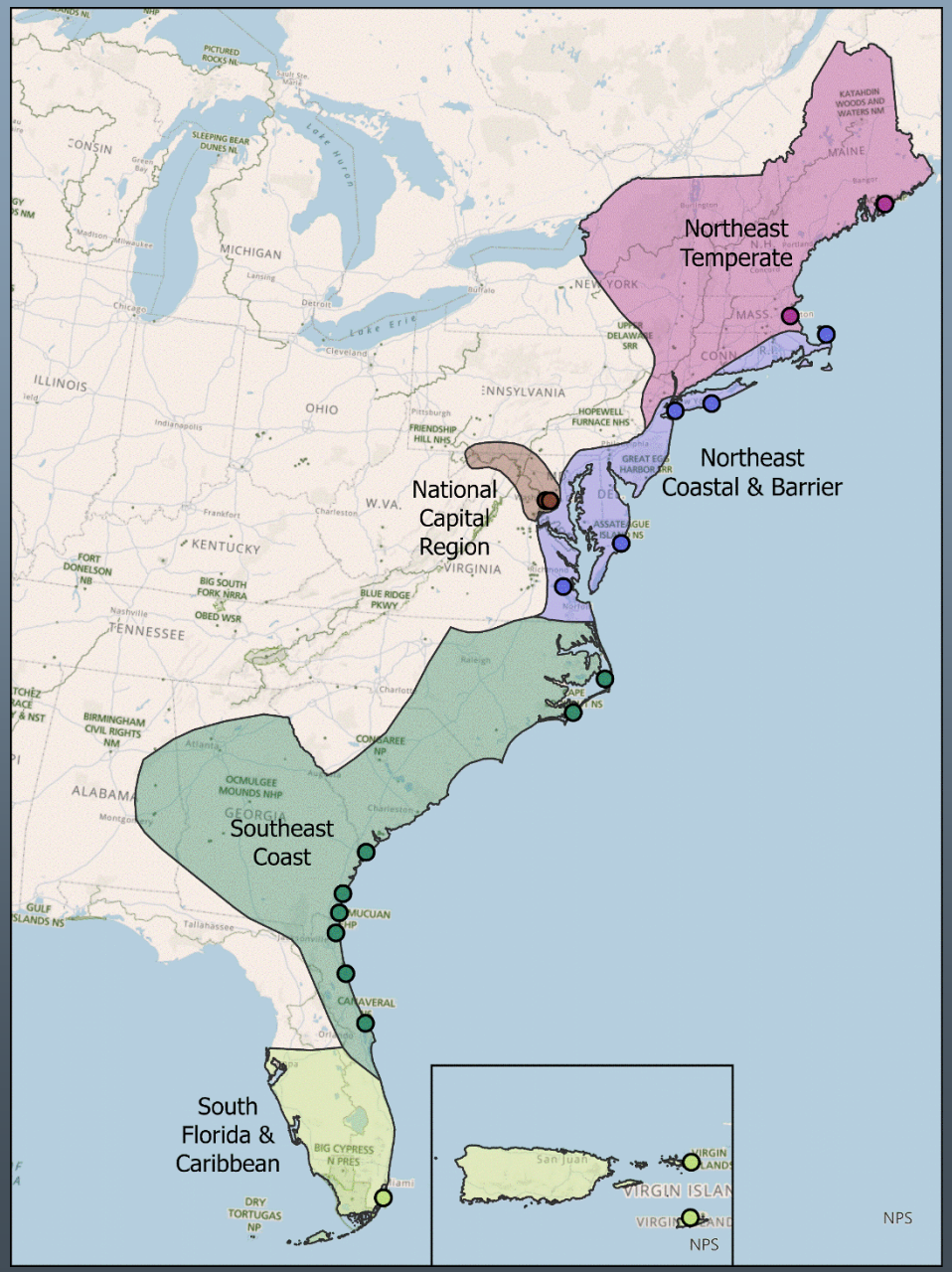
Inventory and Monitoring Division (U.S. National Park Service)

1. Northeast Coastal & Barrier I&M Network

What we monitor:

- Wetlands
  - Vegetation
  - Elevation
  - Nekton
- Coastal Geomorphology
  - Shoreline position
  - Coastal topography
- Estuaries
  - Seagrass
  - Water quality
- Upland Forests
- Weather & Climate

1. NPS I&M Network SETs



Northeast Temperate Network (NETN): Acadia, Boston Harbor Islands

Northeast Coastal & Barrier Network (NCBN): Cape Cod, Fire Island, Gateway NRA, Assateague, Colonial NHP

National Capital Region Network (NCRN): George Washington PKWY, National Capital Parks East

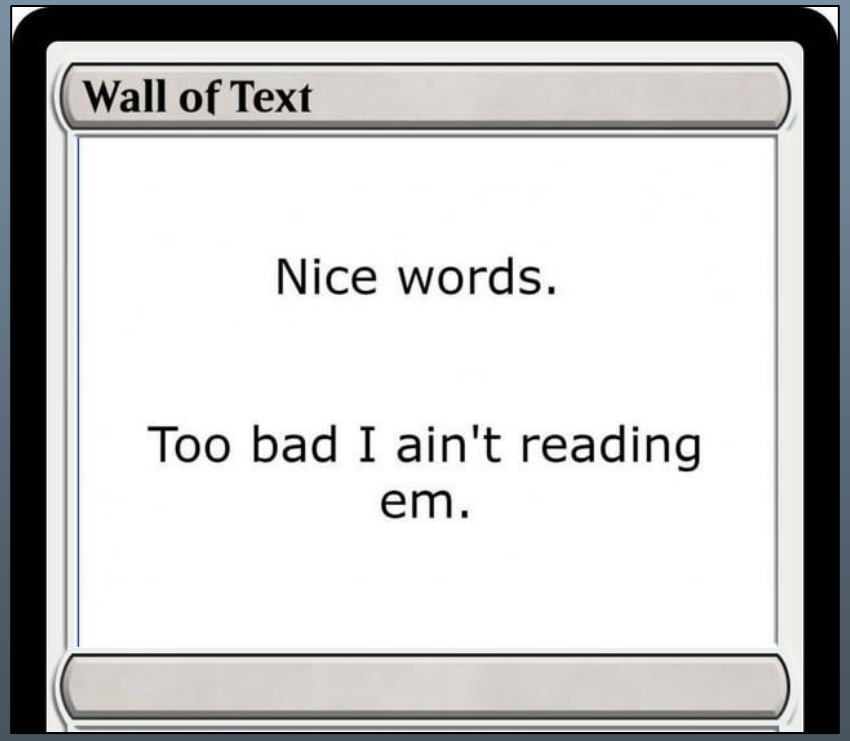
Southeast Coast Network (SECN): Cape Hatteras, Cape Lookout, Canaveral, Cumberland Island, Ft. Frederica, Ft. Matanzas, Ft. Pulaski, Timucuan

South Florida & Caribbean Network (SFCN): Biscayne, Salt River Bay, Virgin Islands

*NPS SET data available at: https://irma.nps.gov/DataStore/Reference/Profile/2305161

Wall of Text Incoming

Make sure you check the notes on each slide!



Github laura-feher/SECOORA-2025

2. The SET Data Lifecycle

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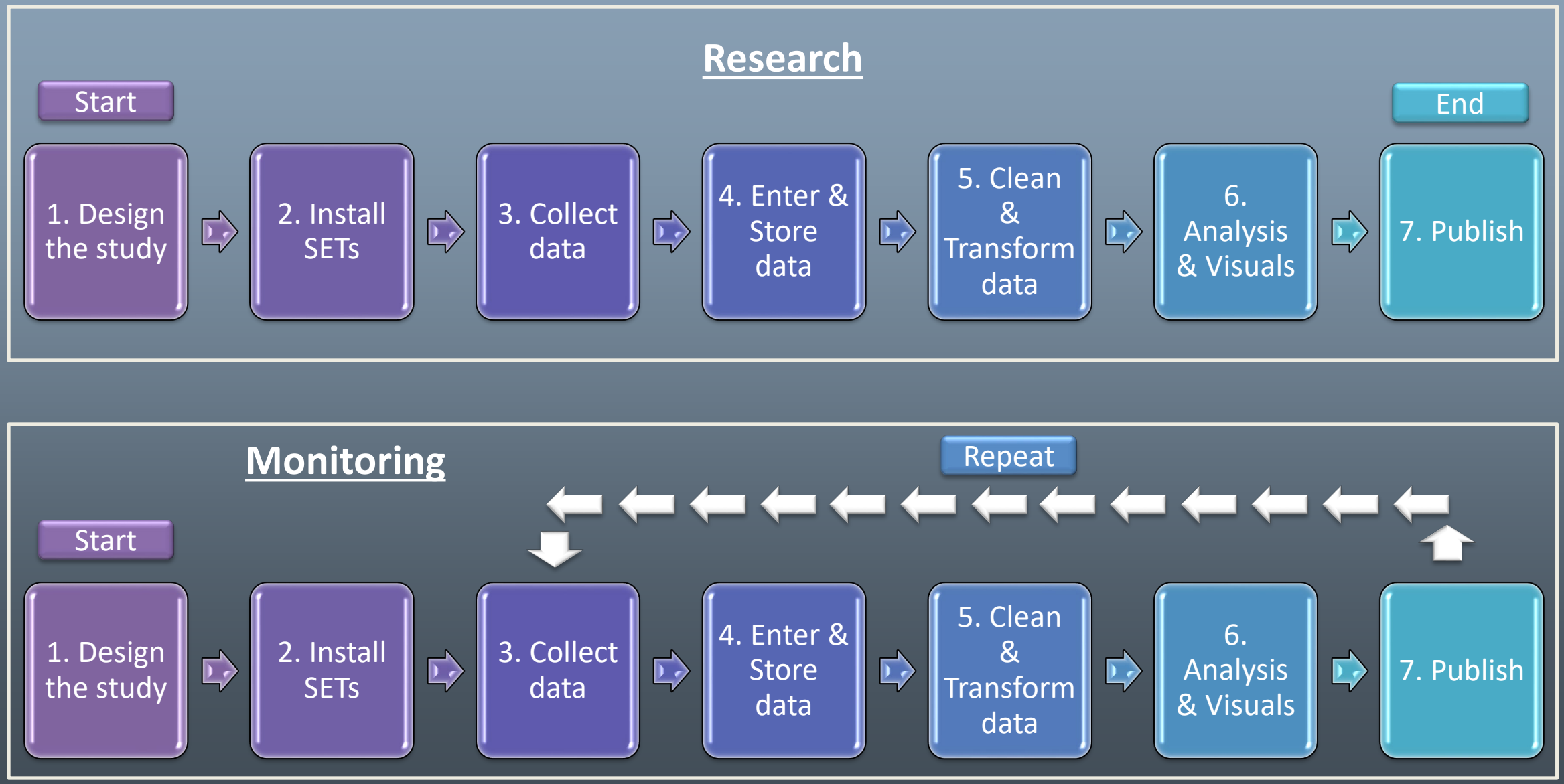


3. Research VS Monitoring

Research	Monitoring
Address specific questions	Document current conditions & assess changes over time
Unknown future paths	Well defined future paths
Study-specific methods of data collection and analysis	Standardized methods and routine data collection and analysis
Expands the bounds of existing knowledge	Needed for regulatory requirements or to inform resource management
Peer-reviewed literature *(reports less common)	Reports *(although journals becoming more common)
LTER experiments	NPS I&M, NEON

- SET studies incorporates elements of both
- Some SET studies are conducted for research, some for monitoring; many are for both
- Results from research studies can be used for monitoring and vice-versa

Both are very good and important!

3. Research VS Monitoring

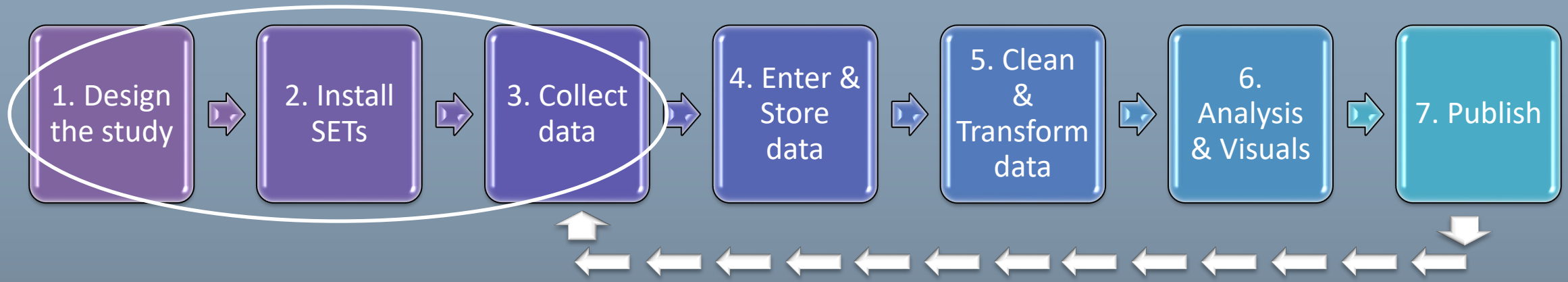
- Academic institutions focus on teaching/doing research (this is good!)
- Monitoring often viewed as a management activity that is unrelated to scientific research
- On an individual level, many of us might not be super excited about monitoring work:
  - We want to do “fun” stuff – not sitting in front of a computer
  - We want the shiny new thing – not doing the same things on repeat
  - We spend too much time getting $, teaching/supervising – limited time for seemingly non-urgent tasks
- On the institutional level, research studies have also been favored due to:
  - Lower cumulative costs
  - Fewer long-term staffing and $ commitments
  - Need to finish so students/post-docs can move on
  - PI career incentives for getting more grants and rapid output of novel findings

3. Research ~~VS~~ And Monitoring

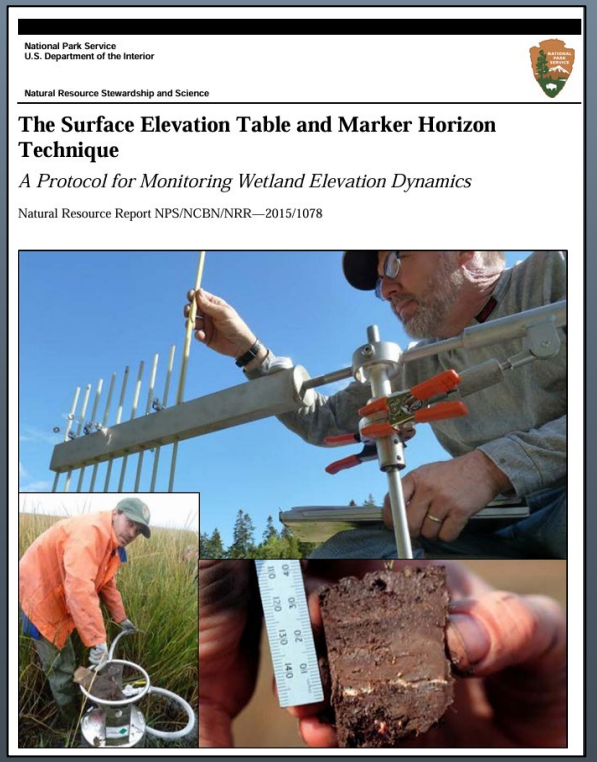
Thus, we receive little training as students and spend little time in our careers developing experience in monitoring skills and processes e.g.,

- Data management, fidelity, documentation, and publication
- Statistical methods for “living” data
- Reproducible research
- Effectively communicating results to stakeholders, resource managers, or non-technical audiences

3. Research and Monitoring: The SET Context



- Steps 1-3 are well defined by a multitude of prior SET publications, Cahoon et al. 2002ab, and the NPS SET protocol (Lynch et al. 2015).
- Standardization in these steps is a HUGE strength of the SET method.
- Rates of change derived from SET data at any one site are directly comparable to other SET data and to rates of SLR.


National Park Service
U.S. Department of the Interior

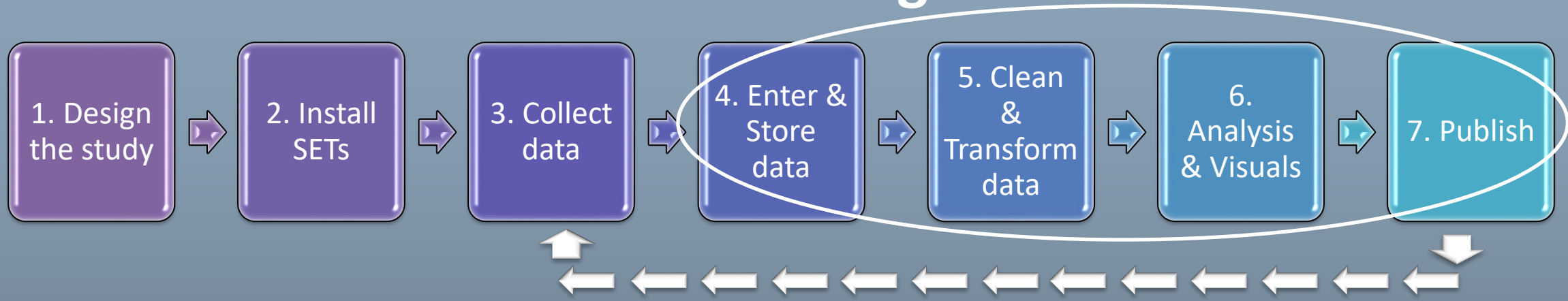
Natural Resource Stewardship and Science

The Surface Elevation Table and Marker Horizon Technique

A Protocol for Monitoring Wetland Elevation Dynamics

Natural Resource Report NPS/NCBN/NRR—2015/1078

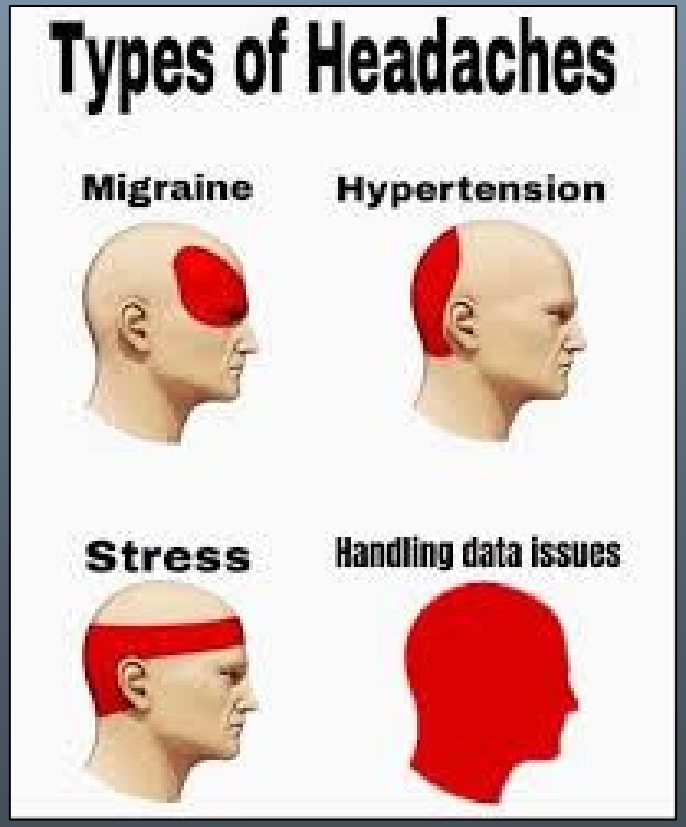
3. Research and Monitoring: The SET Context



- Steps 4/5. Enter, Store, Clean, & Transform data:
  - Most groups develop their own stand-alone procedures
  - May or may not include documentation and publication of data
- Step 6. Analyze & Visualize data:
  - Use of linear regression is standard but there is variation in implementation details– see Russell et al. 2022
  - Many different software options
- Step 7. Publish:
  - Peer-reviewed papers, conference presentations, reports & "grey" literature
  - Web-based reports or interactive visualizations (rare)

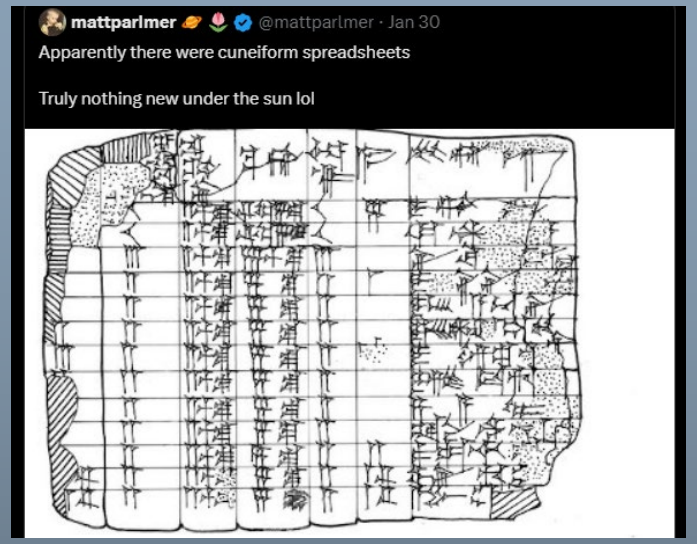
4. Common SET Data Issues

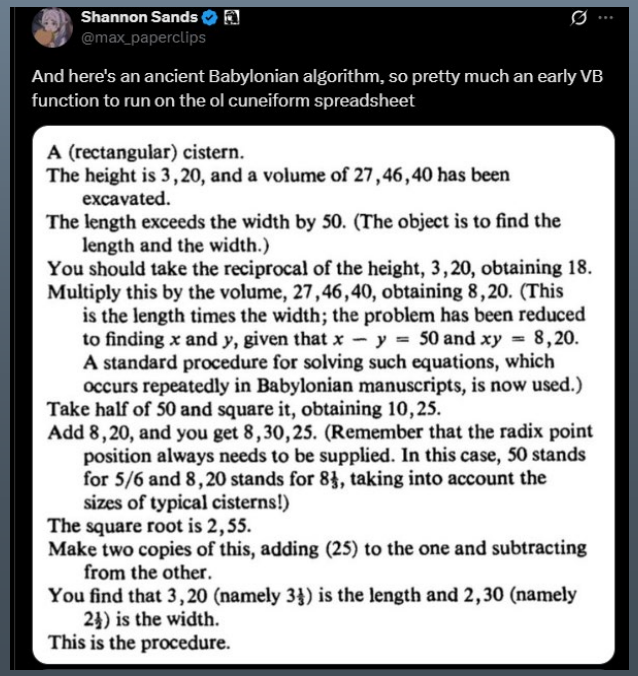
Shame is not the point!



4. Common SET Data Issues

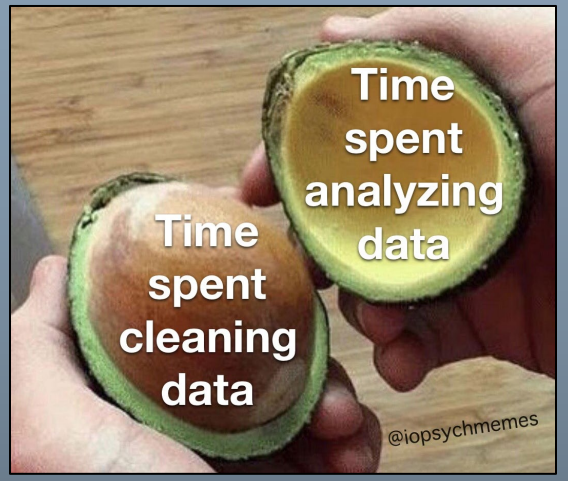
- Limited experience and emphasis on data management, QAQC procedures, reproducible analyses (i.e., previous slide #11)
- “Not Invented Here” syndrome/reinventing the wheel
- Tools/processes developed by other groups are either not shared or are not easily discoverable
- Processes for data management and QAQC are often not documented in detail (or at all)
- Unsure how to adapt and integrate tools/processes developed by other groups
- Frequent personnel changes + lack of defined roles and responsibilities

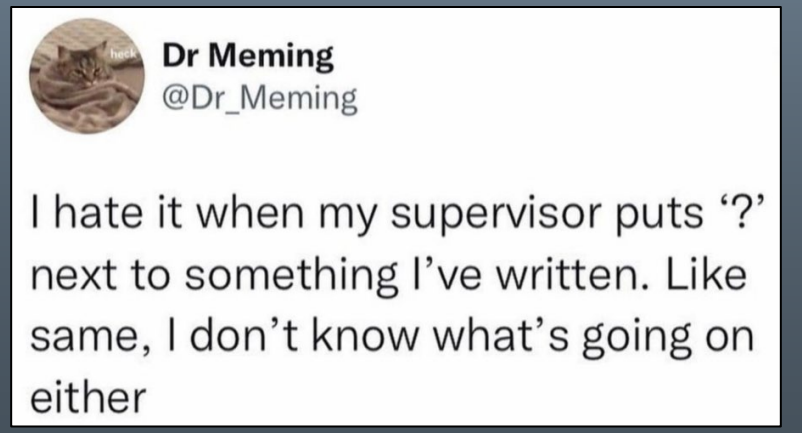




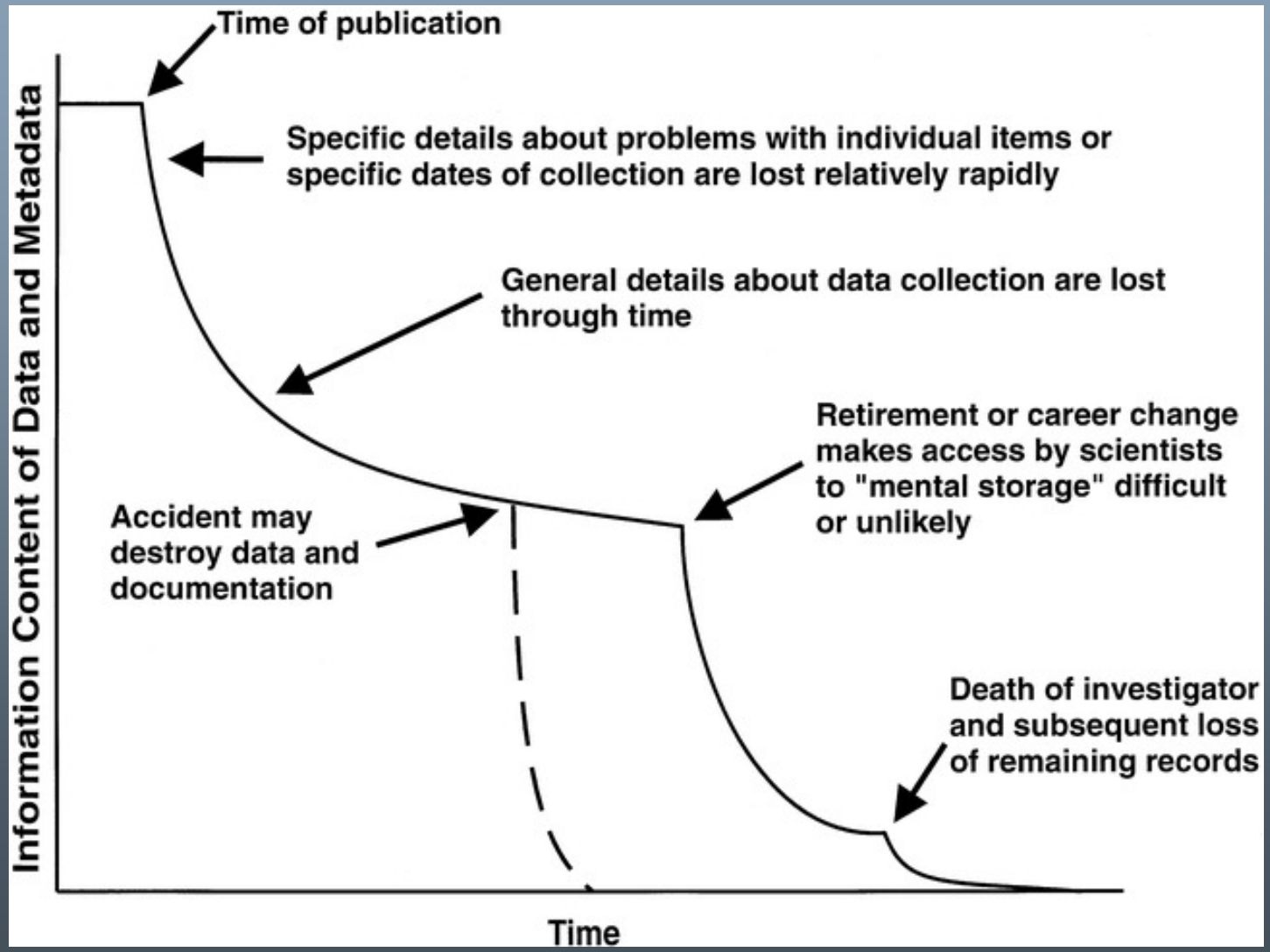
4. Common SET Data Issues: Why You Should Care

- Impacts to productivity:
  - Wasted time/effort trying to find files or determine which data file is correct
  - Wasted time/effort organizing or cleaning untidy data
  - Less time/effort available for field work, analysis, publication, etc.
- Impacts to long-term sustainability:
  - Losing or forgetting important information
  - Introduction of errors or loss of data
  - Unable to replicate steps used for previous QAQC and analyses (can't update results)





4. Common SET Data Issues: Why You Should Care

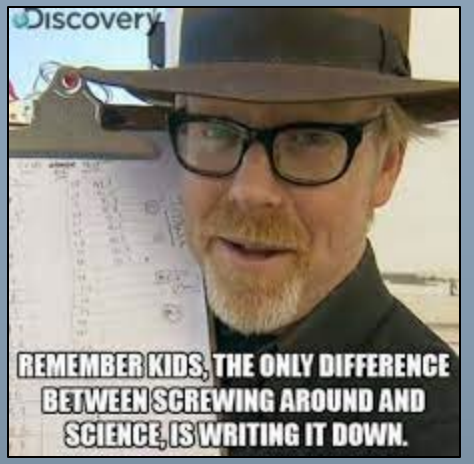


Michener et al. 1997

5. Fortifying the SET Data Lifecycle: Discuss & Get Buy-in

- Meet regularly to identify what is/isn't working
  - E.g., Yearly operational reviews conducted by NPS I&M networks
- Clearly define roles & responsibilities
- Consider potential downstream effects
- If you're happy with your current system, keep it
- Drastic changes are likely unnecessary and can hurt you
  - Focus on simple fortifications – e.g., documentation, organize files, develop a field data sheet
  - Then maybe get more advanced – e.g., databases, packaging code, automated reporting
  - Get buy-in

5. Fortifying the SET Data Lifecycle: Document Everything



- Get things out of your brain and on paper
- Write SOPs - be specific and include pictures
- Think about what someone will need to know to take over if you leave

File naming conventions	Folder structures	Data entry procedures	QAQC procedures
Data processing steps	Data analysis formulas/code	Data visualization templates/code	Data reporting templates/code
Metadata creation	Data publication procedures	Important metadata & logistics	Protocol deviations

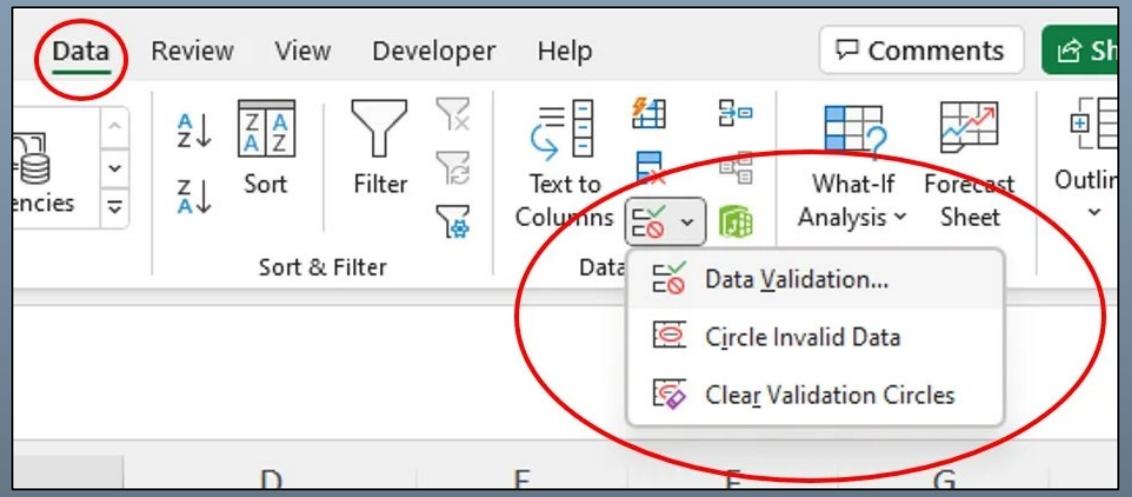
5. Fortifying the SET Data Lifecycle: SET Data Entry & Storage

Enter & Store data

- Establish standardized file naming and folder structures
- Template a field data sheet and stick to it
- Spreadsheets are great for data entry/storage
- Recommendations for excel data entry/storage:
  - Treat raw data as read-only
  - Use “versioning”
  - Store notes separately from raw data
  - Incorporate controls for data entry errors, alterations, or deletions
- FAIR data: Findable, Accessible, Interoperable, Reusable

5. Fortifying the SET Data Lifecycle: Doing Stuff with SET Data

- Use programming tools whenever possible
- "Point-and-click" software is also fine but requires caution
- Create an excel template with built-in data validation, conditional formatting, formulas, actions, etc.
- Document the "whys"
- Keep it human-readable
- Create reusable functions & limit copy-paste
- Package/share your code
- Document the full workflow – e.g. enter raw data in excel -> transform/analyze using "XYZ.R" -> export results to tables in word doc

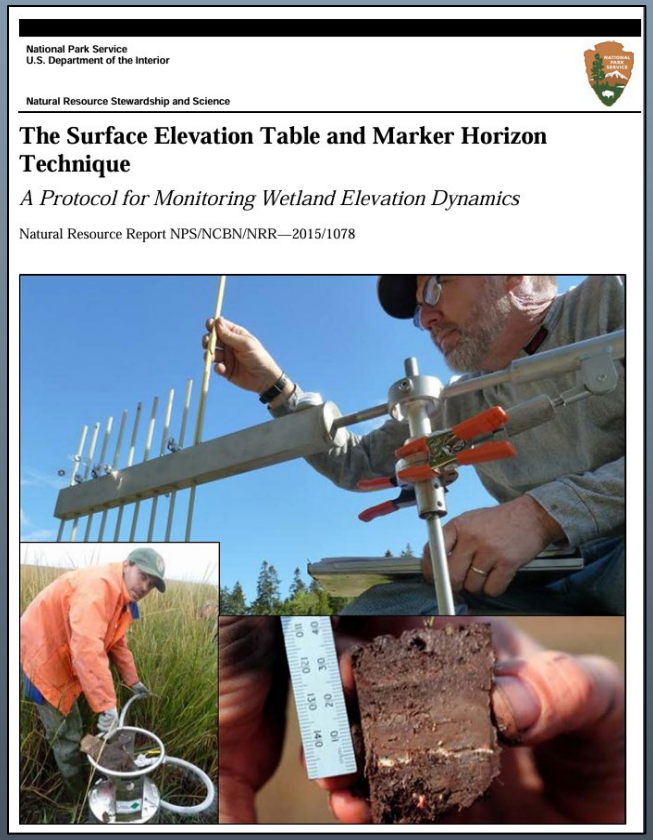



```
#' A Cat Function
#'
#' This function allows you to express your love of cats.
#' @param love Do you love cats? Defaults to TRUE.
#' @keywords cats
#' @export
#' @examples
#' cat_function()

cat_function <- function(love=TRUE){
    if(love==TRUE){
        print("I love cats!")
    }
    else {
        print("I am not a cool person.")
    }
}
```

6. Tools for Fortifying the SET Data Lifecycle: NPS I&M SET Resources

- NPS SET-MH Protocol
  - First published in 2015
  - General SOPs for data management (SOP 7) and analysis (SOP 8)
  - Sample field data sheet and sample data entry/QAQC spreadsheet
  - Version 2.0 coming soon!
- NPS SET Protocol Implementation Plans: Southeast Coast Network, South Florida & Caribbean Network
- NPS SET SOP 2.3.06 – Data Entry (NPS I&M specific)
- NPS SET SOP 2.3.05 – Data QAQC & Publication (NPS I&M specific)
- SET metadata creation templates for use with the NPSDataverse R package – see NPS SET SOP 2.3.05



6. Tools for Fortifying the SET Data Lifecycle: SET-Specific R Resources

- SETr package + NERRS SETr website
  - Developed by Kim Cressman for NERRS SET data
  - QAQC, calculate + visualize cumulative change
  - Will need to transform your data to match the NERRS SET data format

- SETr Reserve Template
  - Developed by Kim Cressman for NERRS SET data
  - R scripts & file structure for the full NERRS SET workflow
  - Includes code and instructions for data entry, processing, analysis, visualizations, reporting

6. Tools for Fortifying the SET Data Lifecycle: SET-Specific R Resources

- NCBN SETr package
  - Borrowed + adapted some functions from Kim's SETr package
  - Standardizes NPS-specific functions for downloading and transforming data
  - Calculate and visualize linear rates of change
  - Download and calculate long-term and/or recent SLR from nearest NOAA station
  - Will need to transform your data to match the NPS format
  - An example of adapting tools developed by other groups to suite my needs.
- SET-viz package
  - Developed by Ellen Cheng for NPS SET data
  - Dashboard-style interactive visuals for QAQC
  - Will need to transform your data to match the NPS format
  - See NPS SET SOP 2.3.05 for instructions

6. Tools for Fortifying the SET Data Lifecycle: Other Relevant Resources

- Russell & Cressman 2025 - Building trust with and strengthening a large collaborative research group including a team statistician: Lessons learned from SETr and NAMASTE
- Russell et al. 2022 - How should surface elevation table data be analyzed? A comparison of several commonly used analysis methods and one newly proposed approach
- Yenni et al. 2019 - Developing a modern data workflow for regularly updated data
  - UpdatingData.org - tutorial on setting up automated workflows for checking and processing regularly-updated data
  - Living data starter repository - template Github repo for regularly-updated data
- Data validation in excel - restrict the type of data/values that users can enter

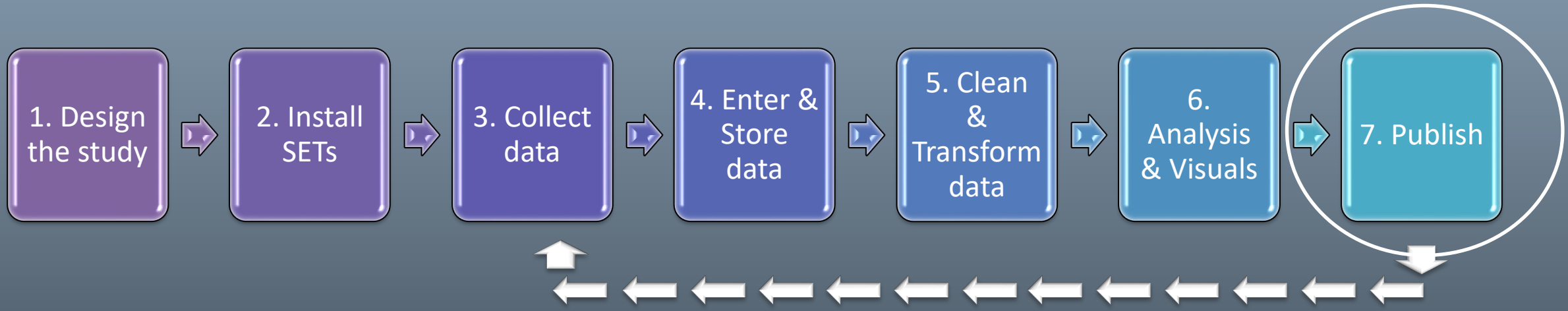
6. Tools for Fortifying the SET Data Lifecycle: Other Relevant Resources

- Happy Git and GitHub for the useR - getting started with version control and code sharing/collaboration in RStudio
- NERRS Guide to Collaborative Science
- A Minimal Introduction to Reproducible Research
- NPS IMD Advanced R Training
- Buckley et al. 2025 - Using dynamic documents to mend cracks in the reproducible research pipeline
- Hampton et al. 2017 - Skills and knowledge for data-intensive environmental research

6. Tools for Fortifying the SET Data Lifecycle: Other Relevant Resources

- Hampton et al. 2015 - The tao of open science for ecology
- Rüegg et al. 2014 - Completing the data life cycle: using information management in macrosystems ecology research
- Data Carpentry: Data Organization in Spreadsheets for Ecologists
- Data Management SOP for the Tampa Bay Estuary Program
- Broman and Woo 2018 - Data organization in spreadsheets
- White et al. 2013 – Nine simple ways to make it easier to (re)use you data.

7. Strategies/Examples of Integrating SET Research into NR Management



7. Strategies/Examples of Integrating SET Research into NR Management

7. Publish

Strategy: Identify the most at-risk areas that would benefit from either restoration or conservation

Example: Delgado et al. 2024

- Measured SETs in different marsh zones and used rates of surface elevation change to suggest priority areas for restoration efforts
- "Low marsh along primary channels lost elevation (−11.57 mm $year^{-1}$), while the mid-high marsh gained elevation (+2.65 mm $year^{-1}$)."
- "If restoration is considered in [the Jug Bay] system, it should focus on the vulnerable low marsh zones along primary channels."

7. Strategies/Examples of Integrating SET Research into NR Management

7. Publish

Strategy: Identify successful (or unsuccessful) management actions and quantify the degree of impact

Example: Staver et al. 2024a (also see Staver et al. 2024b)

- Used SETs to measure surface elevation change in marshes created from "fine-grained, nutrient-rich dredged material from upper Chesapeake Bay" (Poplar Island, MD).
- "Using > 10 years of data from 39 surface elevation tables, we found that the mean low marsh rate of elevation change (7.7 ± 3.21 mm $year^{-1}$) was double the mean high marsh rate (3.6 ± 0.47 mm $year^{-1}$) and exceeded the natural reference marsh (3.0 ± 2.28 mm $year^{-1}$) and relative SLR (5.7 mm $year^{-1}$)."
- "The use of fine-grained dredged material as a substrate for tidal marsh restoration results in marshes that are resilient to RSLR in the first one to two decades of development, supporting the use of this type of substrate for future projects."

7. Strategies/Examples of Integrating SET Research into NR Management

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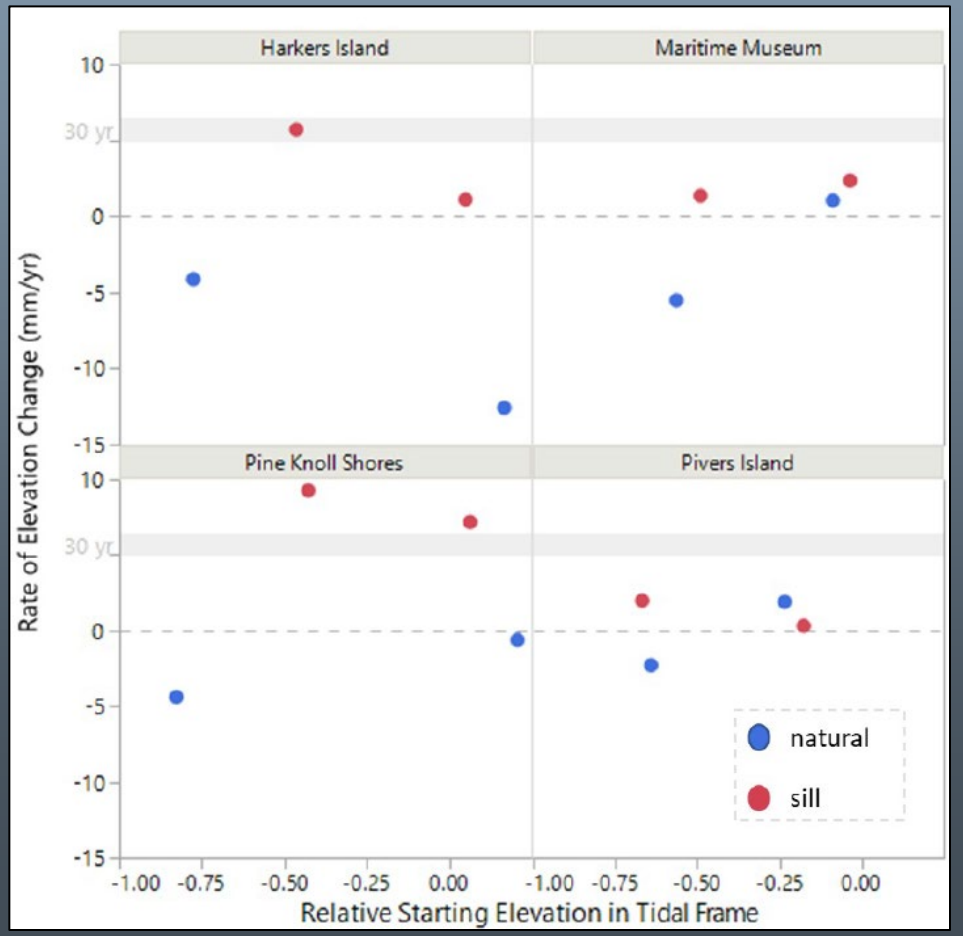
Strategy: Identify successful (or unsuccessful) management actions and quantify the degree of impact

Example: Surface Elevation Trends in North Carolina's Coastal Wetlands

- "In all cases, SETs in marsh sill living shorelines measured net positive elevation gain. In contrast, only two of the eight SETs installed in paired reference marshes measured net increases in elevation over time."
- "Marsh-sill living shorelines can provide protection against erosion and, as demonstrated here, sills can help to promote elevation gain."



7. Strategies/Examples of Integrating SET Research into NR Management

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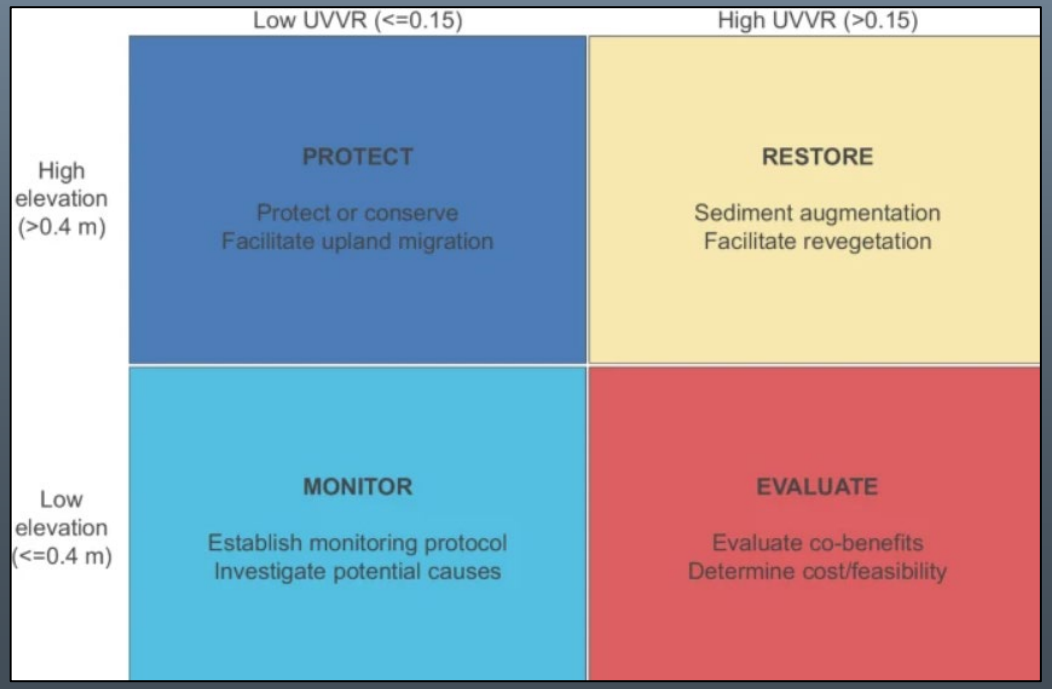
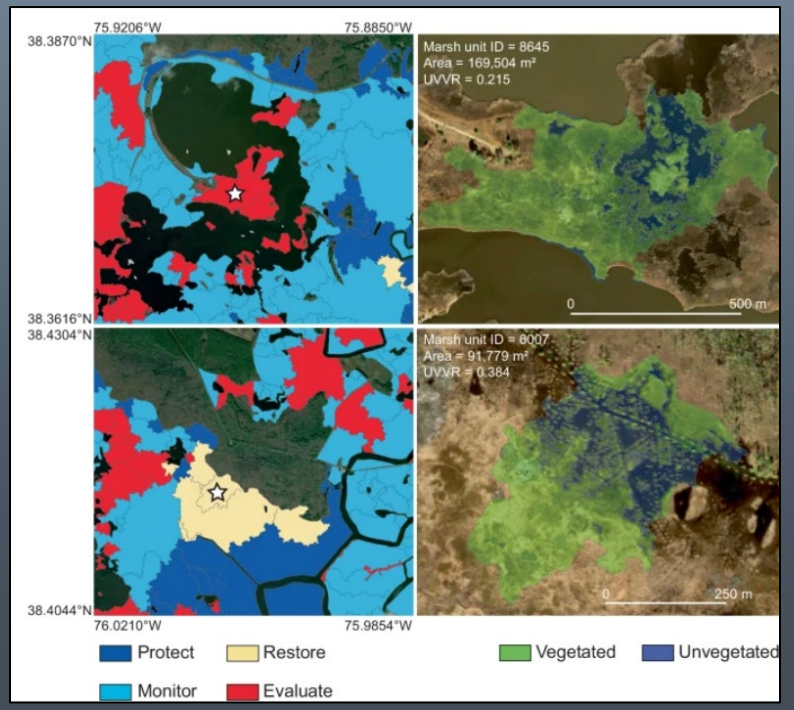
Strategy: Provide generalizable frameworks for decision making and examples of their use

Example: Ganju et al. 2024a and Ganju et al. 2024b

- Combined SET data + UVVR to develop a decision support matrix for use within the RAD framework





7. Strategies/Examples of Integrating SET Research into NR Management

7. Publish

Strategy: Evaluate the current state of the ecosystem and identify specific deficits and need for action

Example: Hartig et al. 2024

- Utilized SET + elevation data to create an index of salt marsh condition
- "Overall, these results aid in evaluating site vulnerability, capacity to accrete sediment, and opportunities for sustainable restoration, particularly with greater tidal inundation of nutrient-enriched waters under accelerated RSLR."
- "The SET-MH network results offered a sense of urgency showing that while there were elevation surpluses and deficits, none indicated long-term stable condition."
- "In mitigating marsh loss, the design grades for our recent wetland restoration projects enlarge the upper elevation ranges of the low- and high-marsh zones and incorporate wider and more gradual slopes in upland transition zones to enable inland marsh migration."

7. Strategies/Examples of Integrating SET Research into NR Management

7. Publish

Effectively communicating results to stakeholders, resource managers, or non-technical audiences requires a different approach than publishing papers:

- Determine what format or type of content would be most helpful to them
- Don't over complicate your methods, results, discussion
- Focus on a small number of take-home messages
- Use visuals to illustrate your main points
- If possible, provide recommendations based on your results *(use with caution)

Example: "We measured surface elevation change in the marsh at Feher's Point between 2010 to 2020 using a surface elevation table (SET). The SET is a portable leveling instrument that measures small changes in the elevation of the marsh over time. The rate of surface elevation change in the marsh was 1.00 mm/yr and the relative rate of sea-level rise over this same period was 5 mm/yr (Fig. 1). Thus, the marsh at Feher's Point is not keeping pace with sea-level rise and will likely be converted to open water by 2050."

7. Strategies/Examples of Integrating SET Research into NR Management

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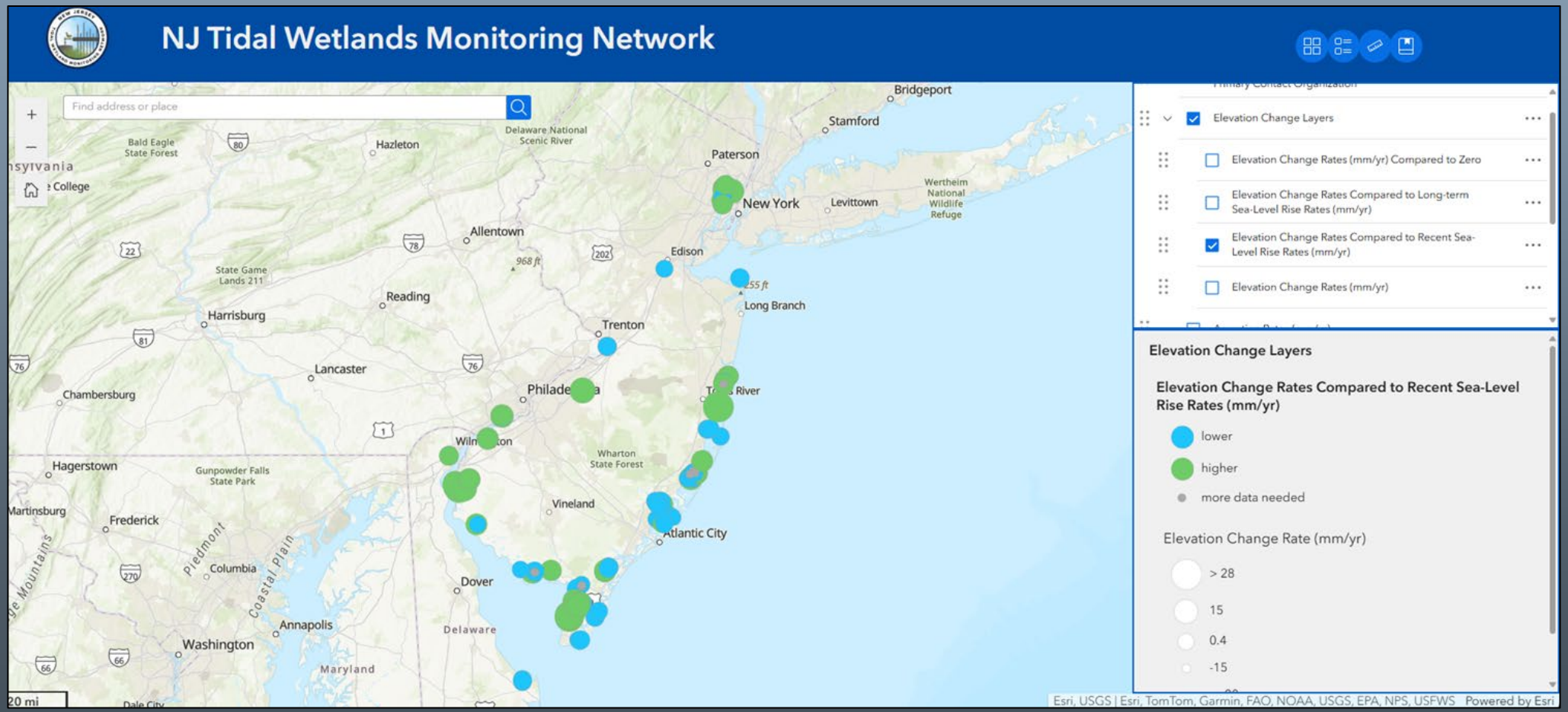

New Jersey Tidal Wetland Monitoring Network (NJTWMN)

7. Strategies/Examples of Integrating SET Research into NR Management

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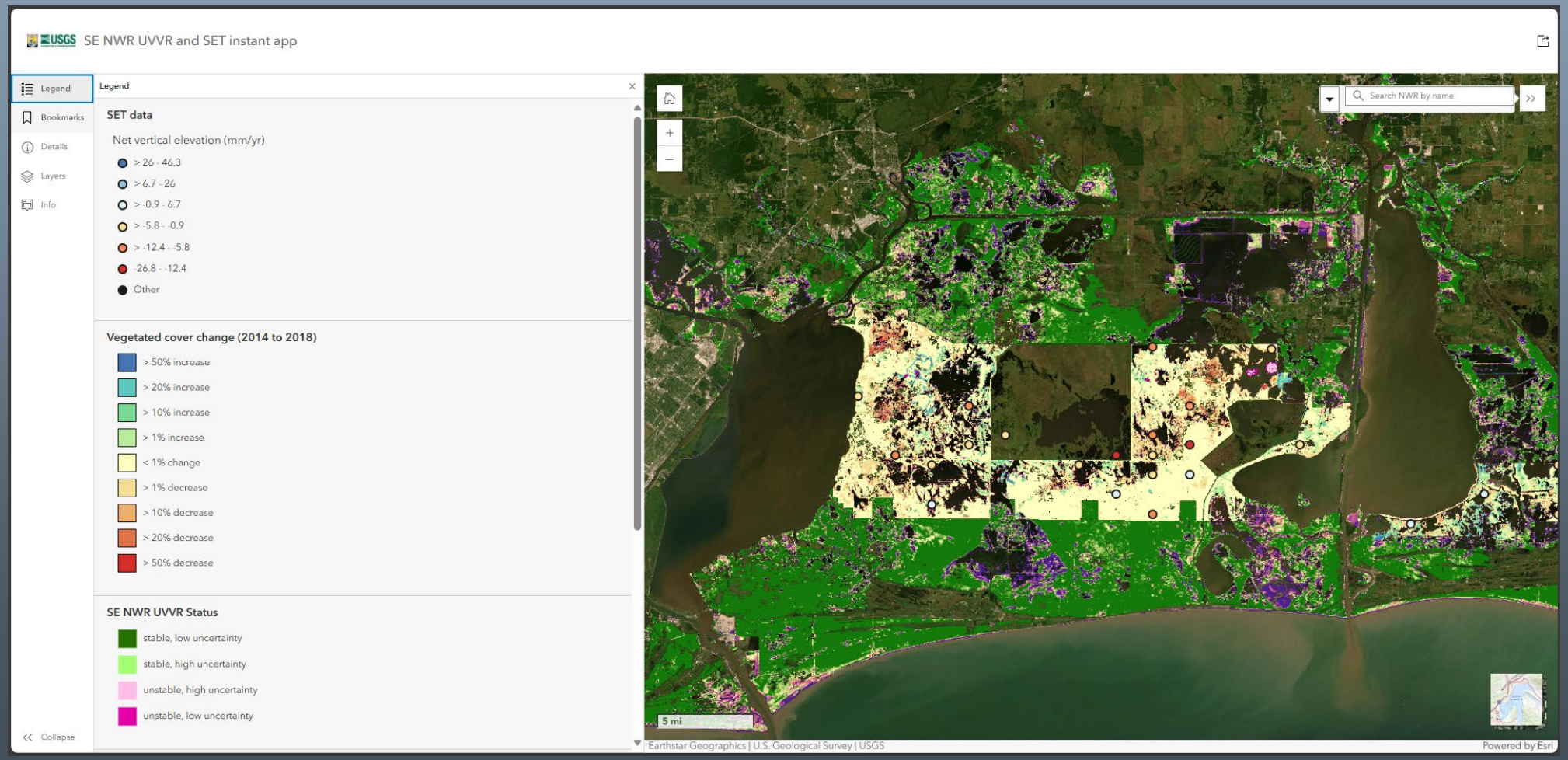

[USGS Coastal Wetland Synthesis Applications]

7. Strategies/Examples of Integrating SET Research into NR Management

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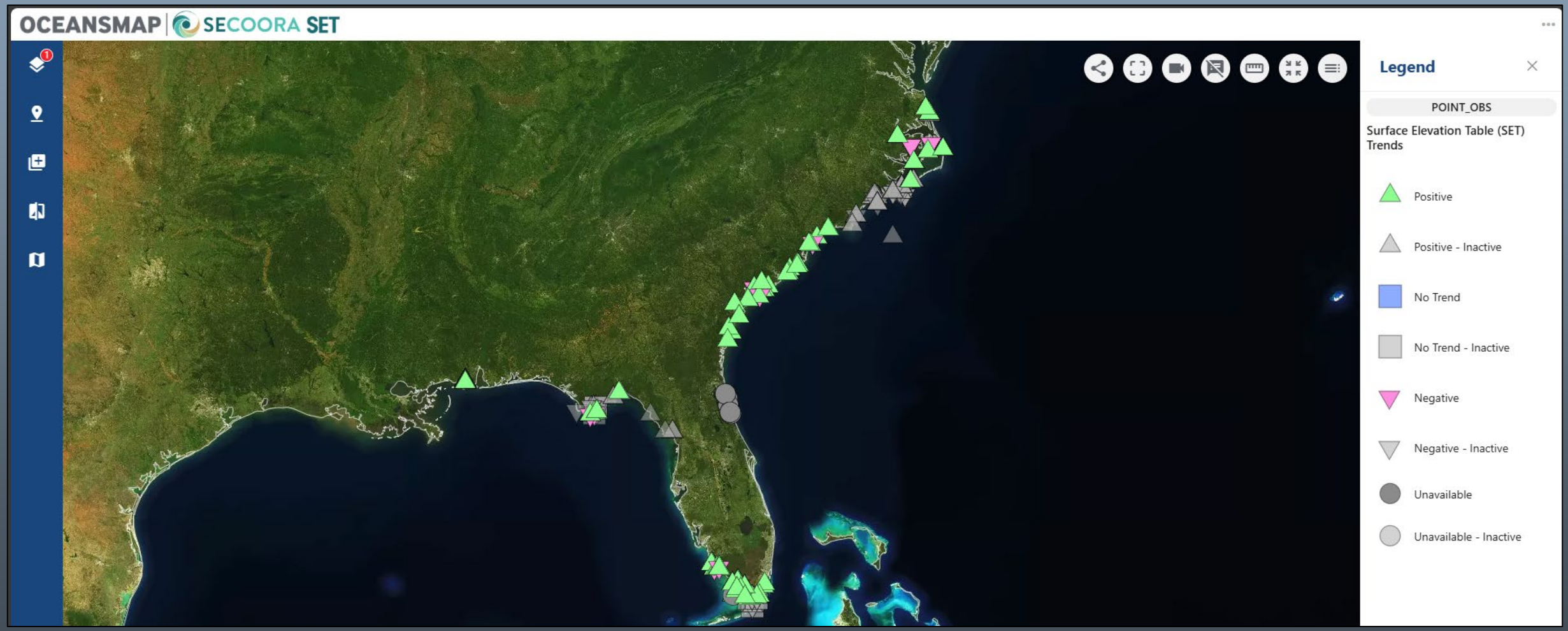

SECOORA SET OceansMap

7. Strategies/Examples of Integrating SET Research into NR Management

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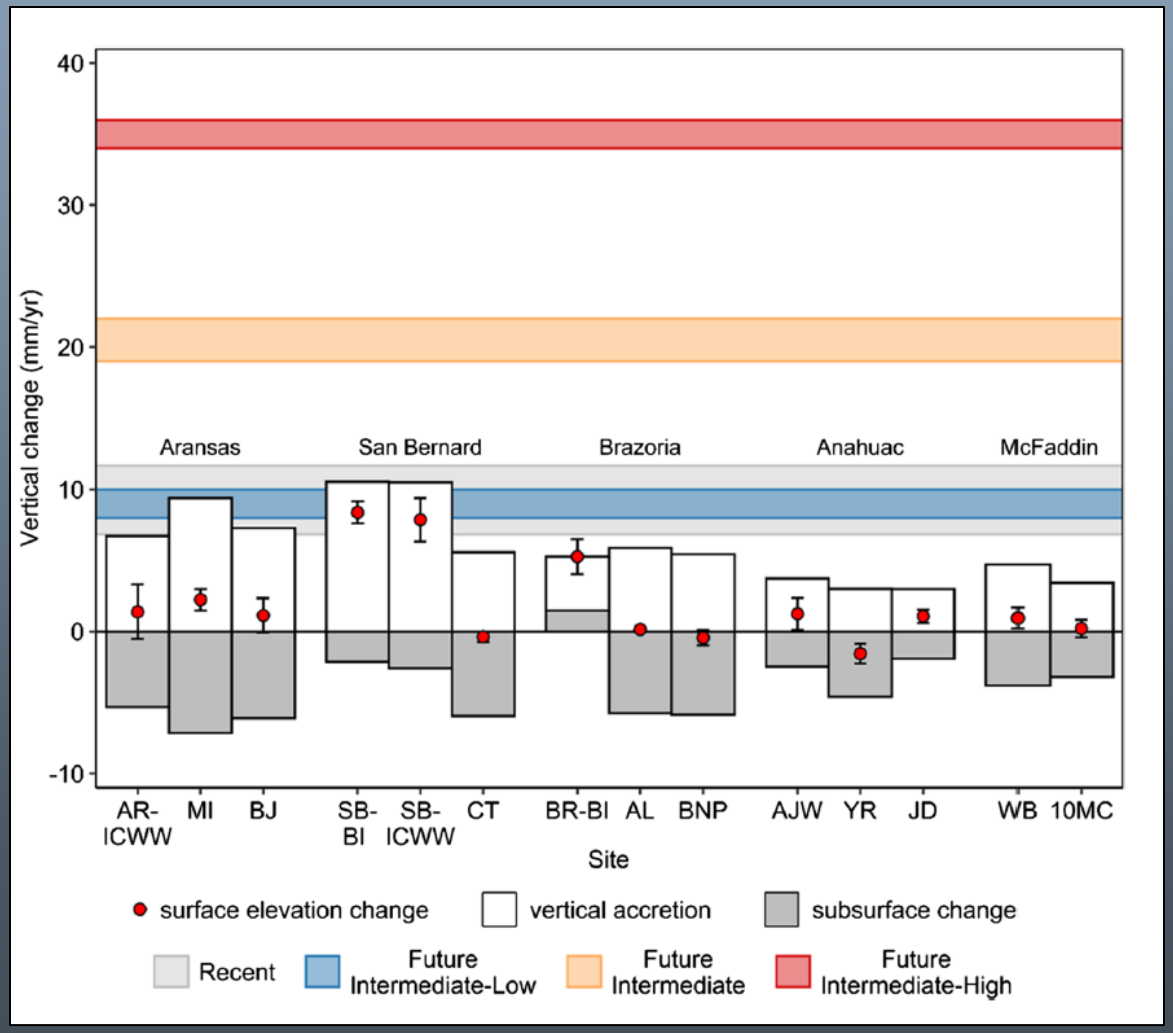

Moon et al. 2022

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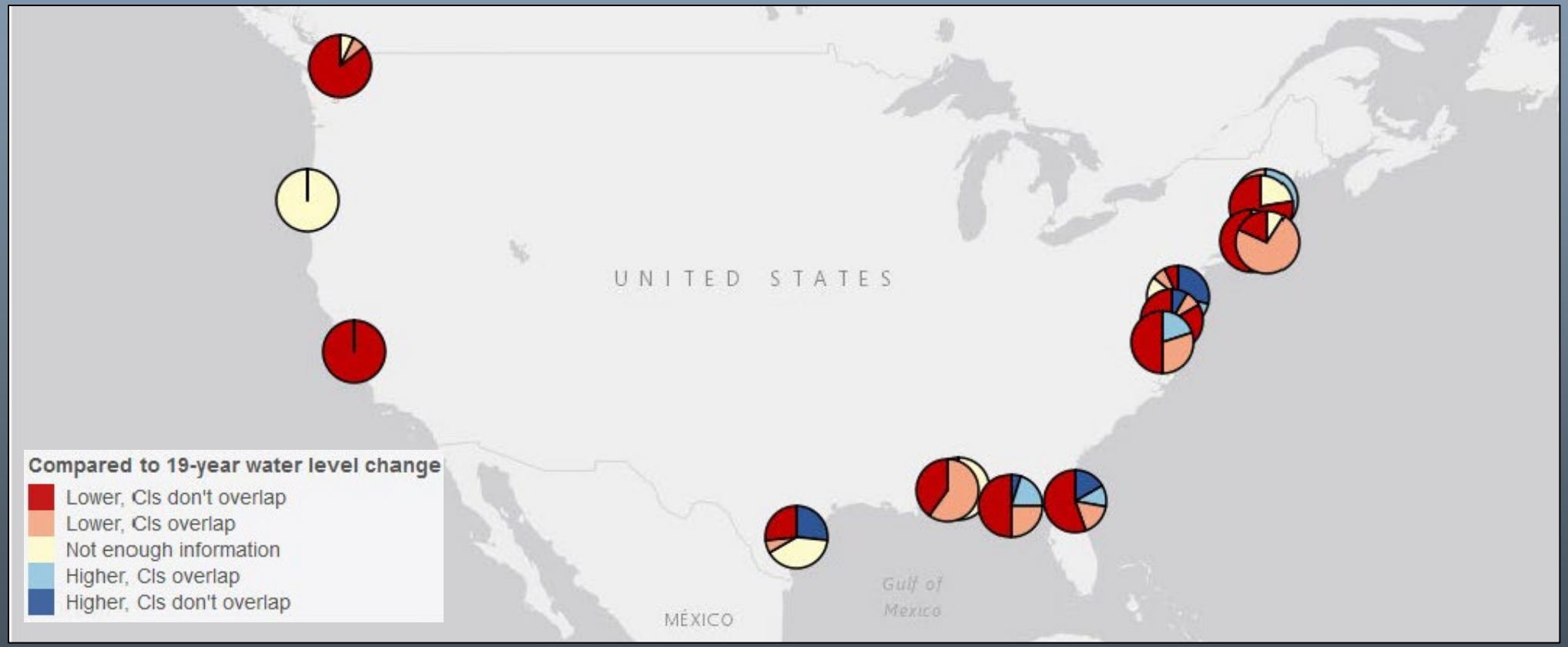
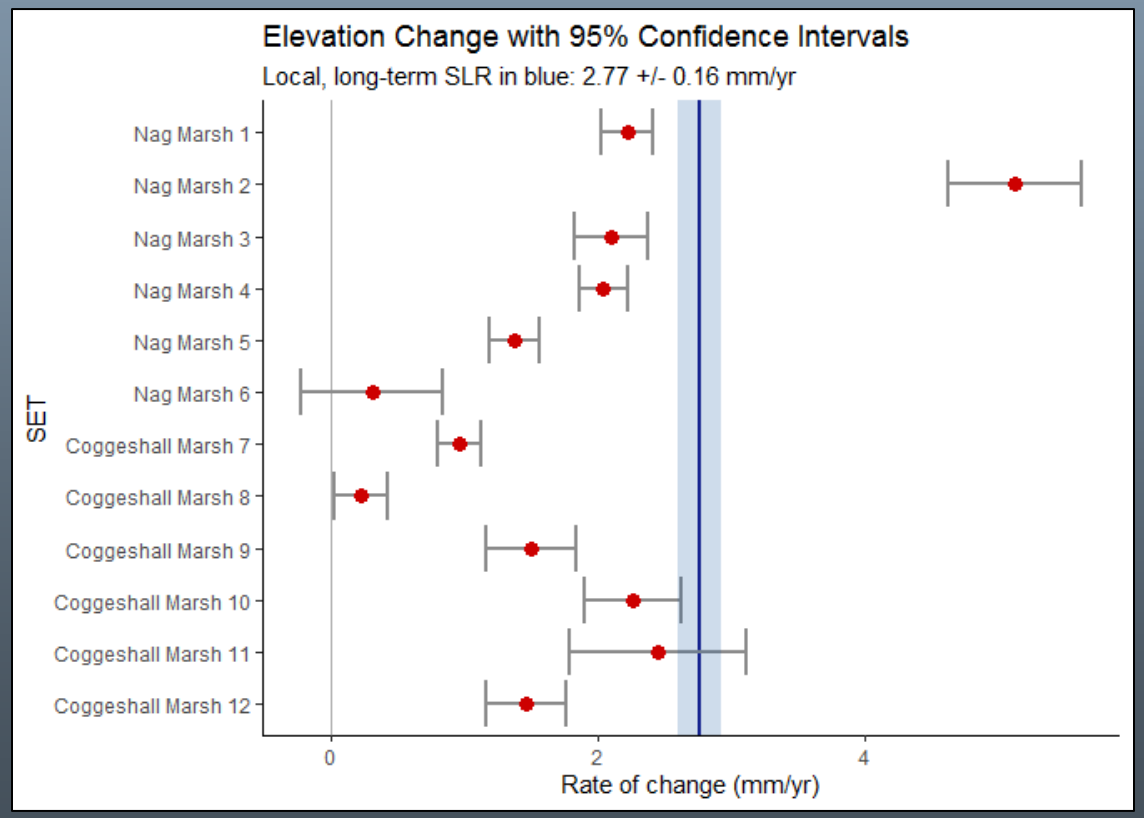


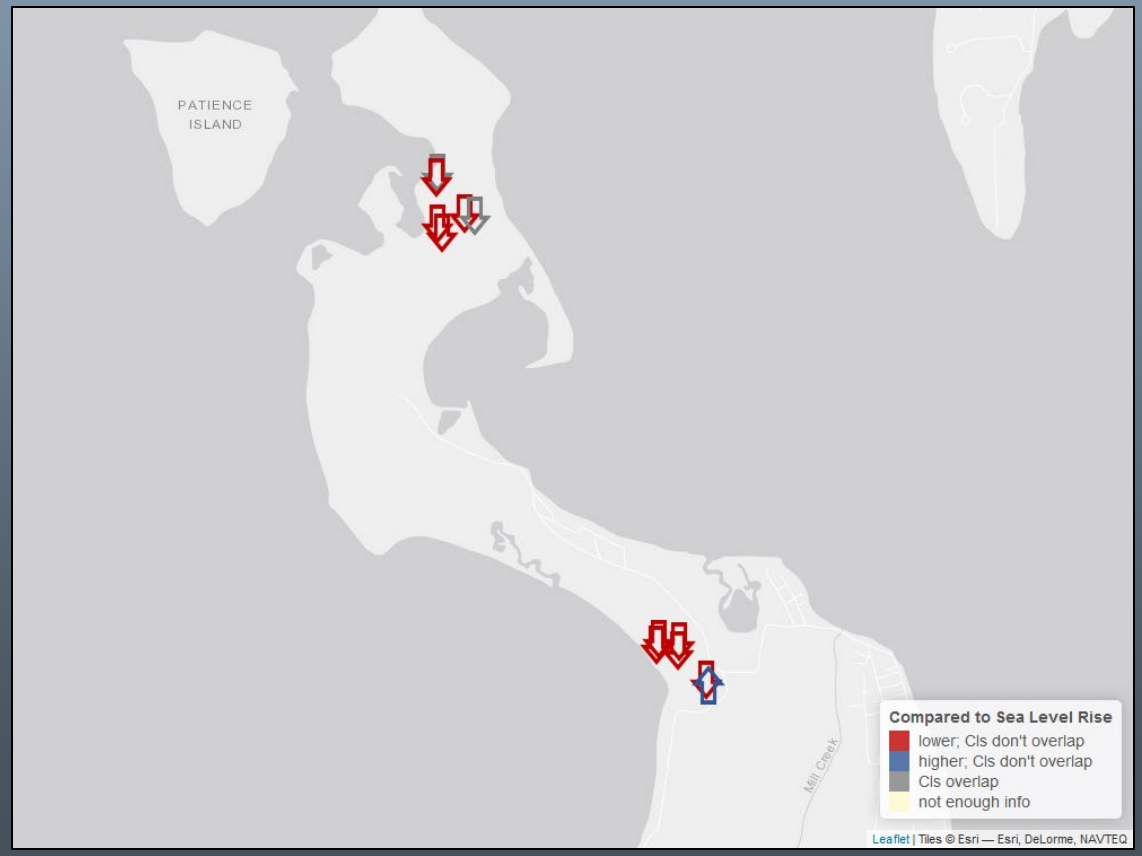
National Synthesis of NERR Surface Elevation Table Data | NERRS Science Collaborative

7. Strategies/Examples of Integrating SET Research into NR Management

7. Publish

Strategy: Effectively communicate results to stakeholders, resource managers, or non-technical audiences





National Synthesis of NERR Surface Elevation Table Data | NERRS Science Collaborative

7. Strategies/Examples of Integrating SET Research into NR Management

7. Publish

Strategy: Effectively communicate results to stakeholders, resource managers, or non-technical audiences

How are Kingman Lake and Kenilworth Marsh Faring?

A 2023 report by Tredennick et al. analyzed marsh monitoring data from 2002-2019 and found that the elevation at Kenilworth Marsh is keeping up with sea level rise while Kingman Lake is not (Figure 1). Even though accretion rates at both marshes show ample sediment inputs, at Kingman the sediment building up is offset by shallow subsidence. These results suggest that the marsh at Kingman Lake may be less resilient to sea level rise.

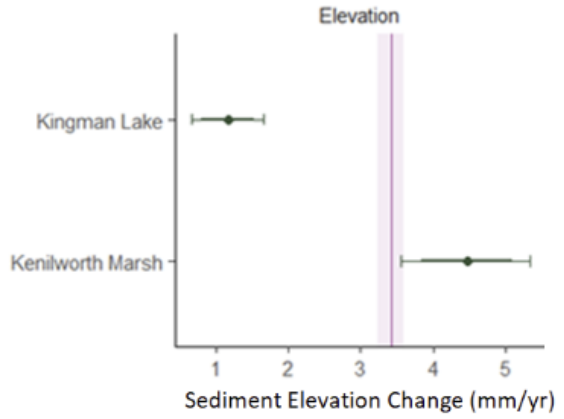


Figure 1: Dots show estimated elevation trends for Kingman Lake and Kenilworth Marsh at NACE. The vertical pink line shows average annual sea level rise. Horizontal bars show 95% credible interval.
NPS

[Long-Term Monitoring Reveals Challenges and Resilience at Dyke Marsh (U.S. National Park Service)]

Acknowledgements

7. Publish

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Northeast Coastal and Barrier Inventory & Monitoring Network (U.S. National Park Service)