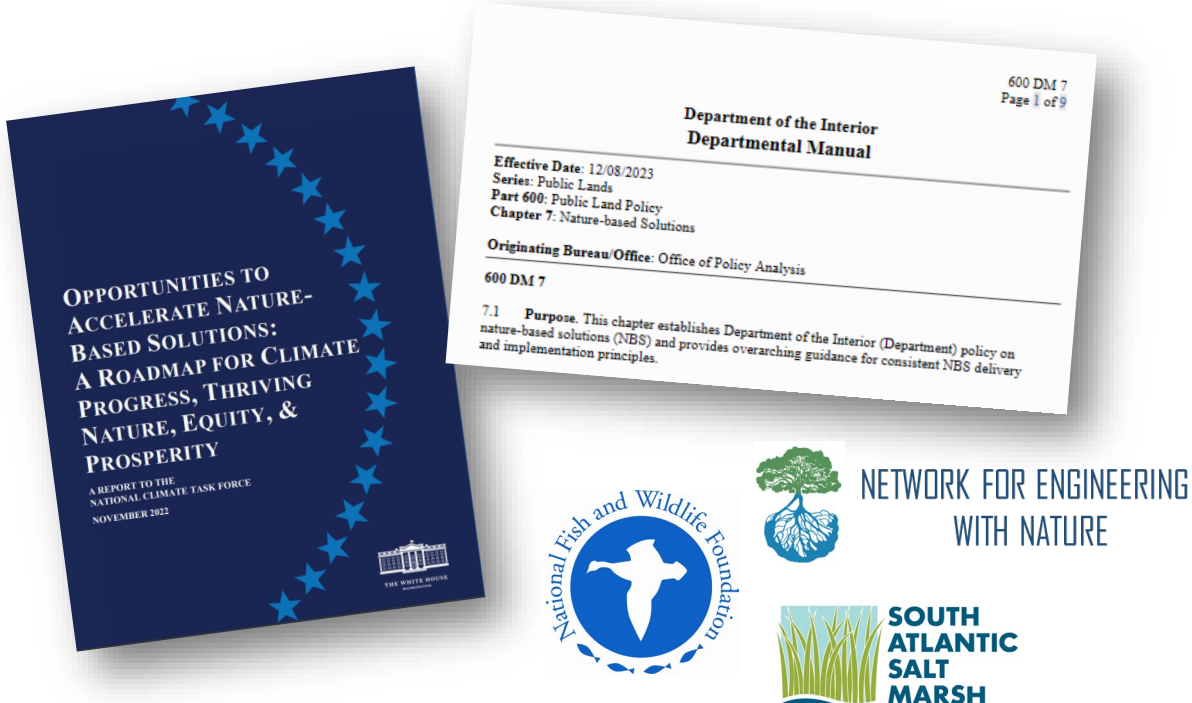
METRICS AND DATA NEEDS FOR NATURE-BASED SOLUTIONS MONITORING, EVALUATION, AND DESIGN GUIDANCE

ACES PANEL SESSION | DEC 2024

LYDIA OLANDER | NICHOLAS INSTITUTE, DUKE UNIVERSITY

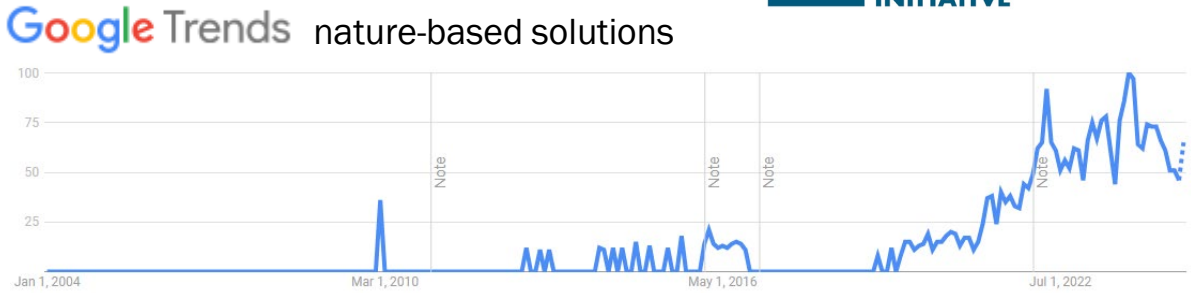
GROWING INTEREST IN NATURE-BASED SOLUTIONS & EFFECTIVENESS INFORMATION



National Fish and Wildlife Foundation

NETWORK FOR ENGINEERING WITH NATURE

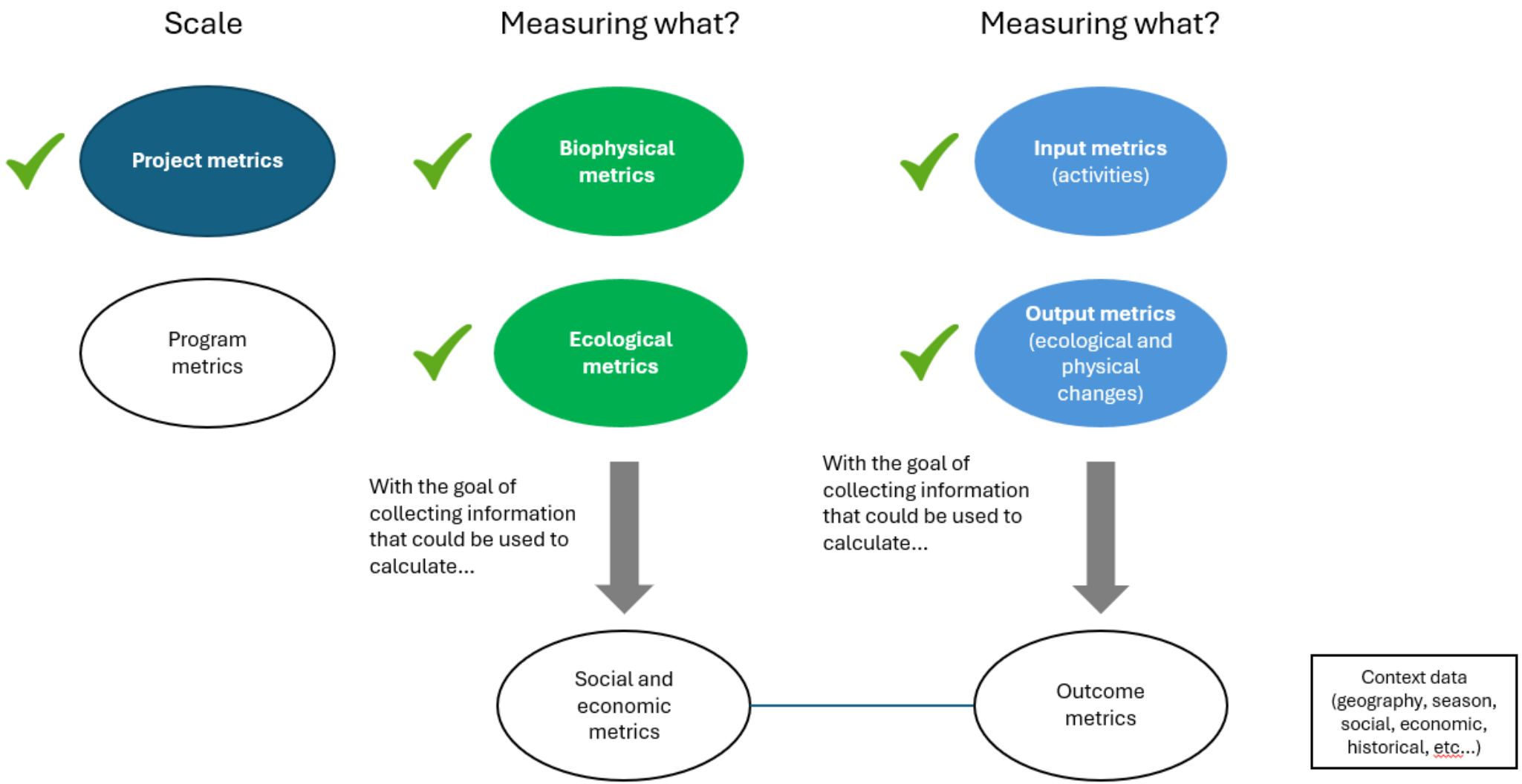
SOUTH ATLANTIC SALT MARSH INITIATIVE



Information needed for:

- Project evaluation & reporting
- Storytelling and awareness building
- Design and engineering standards
- Project planning and siting
- Adaptive management
- Valuing project benefits (BCA) or Making the business case (ROI)
- Pay for success

WHAT TYPE OF METRICS ARE WE TALKING ABOUT?

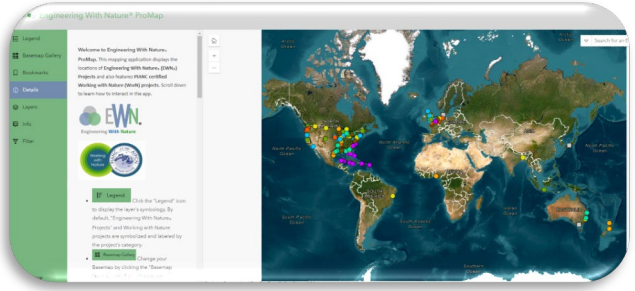


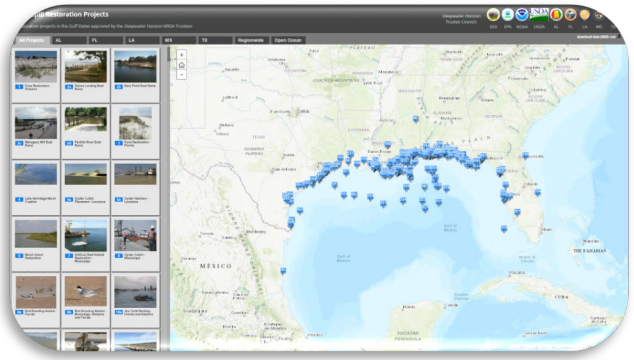
What information is available on NBS effectiveness or for evaluating effectiveness?

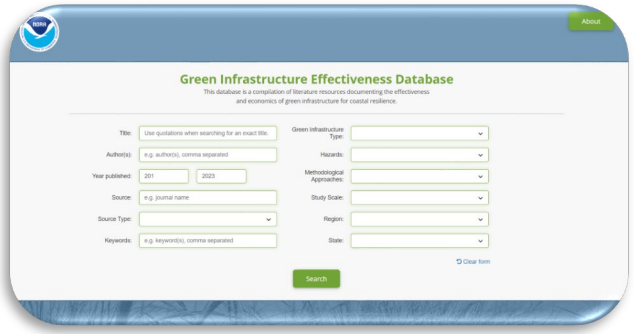
METHODS:

Assessed 6 literature databases and 21 project databases.

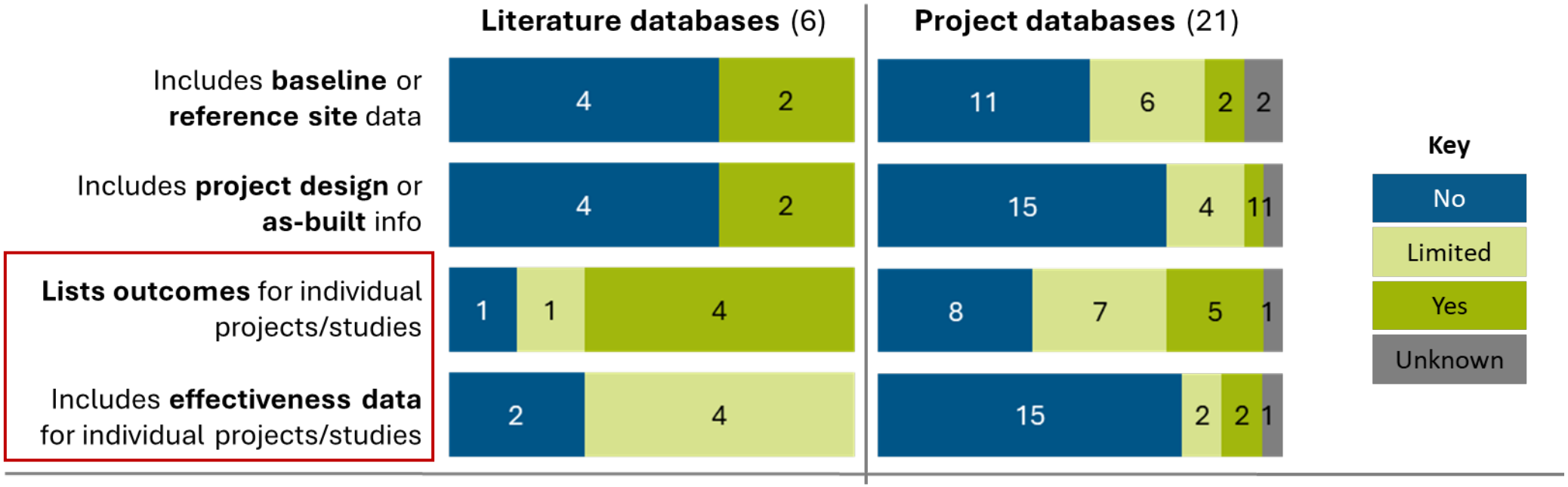
- Evaluated whether information provided could be used to evaluate effectiveness
- Identified gaps in coverage of NBS - geography and NBS type







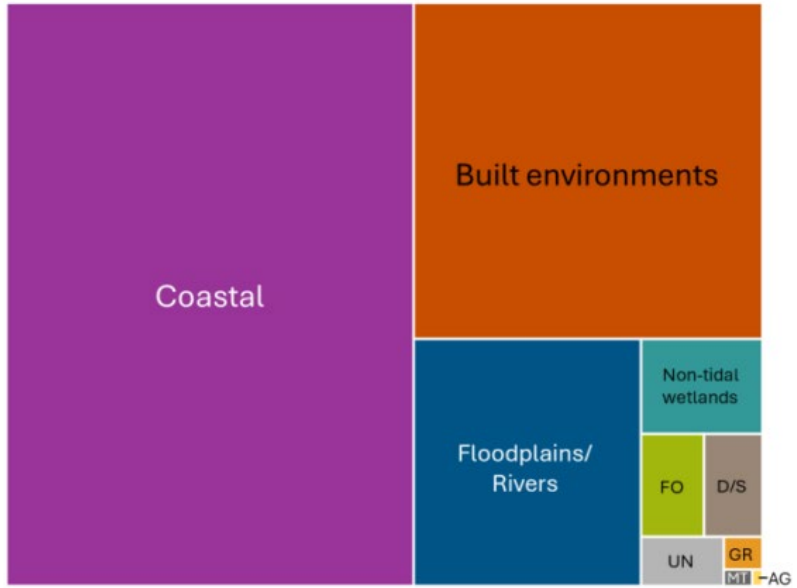
NBS database content & features are not adequate for assessing effectiveness



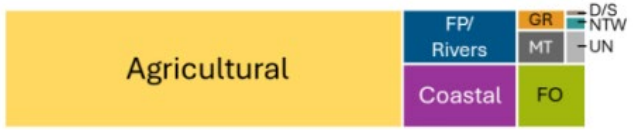
See report for assessment of additional database characteristics
(filter/search functions, download option, update frequency, geographic info, etc.)

Database entries are unevenly distributed across habitats & geographies

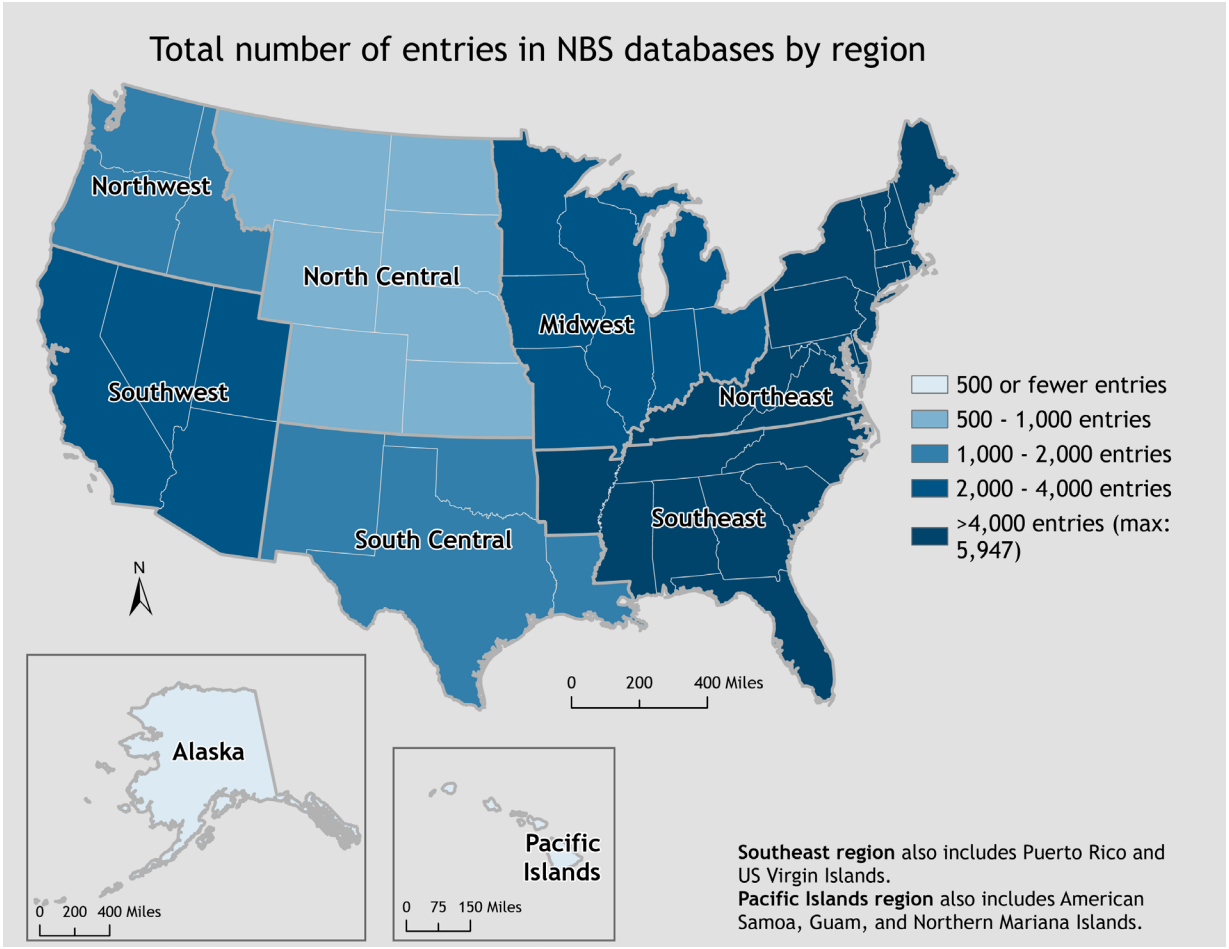
(a) Projects in project databases



(b) Publications in literature databases



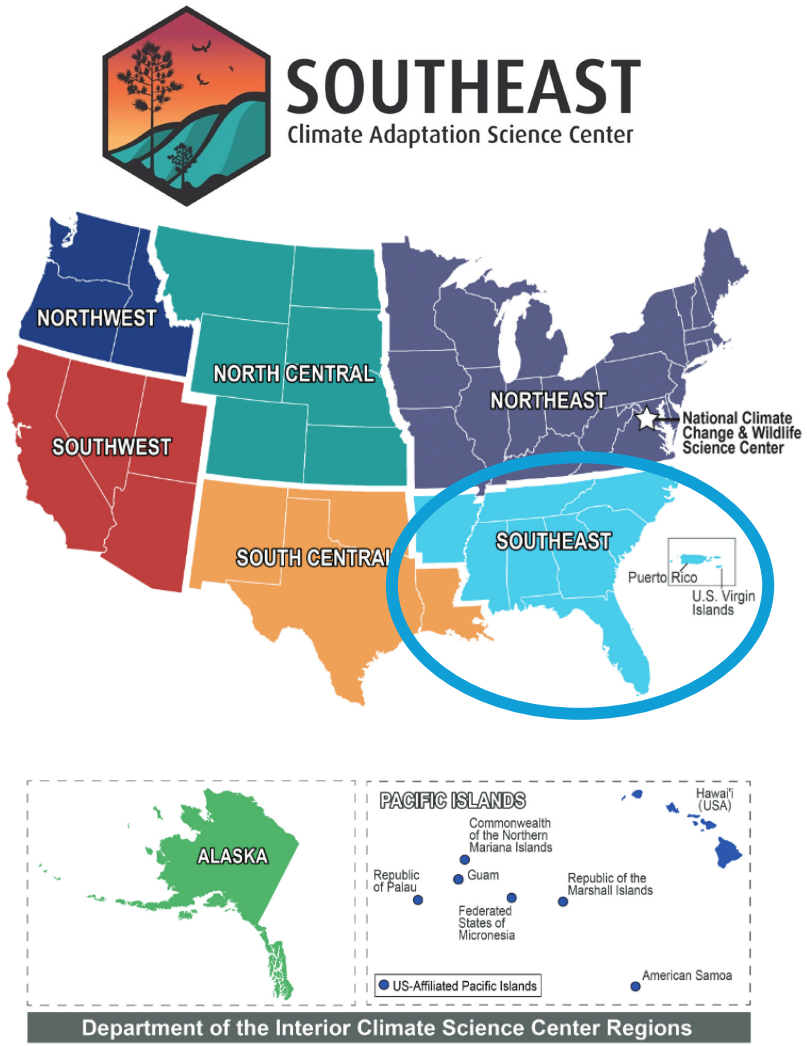
- Non-tidal wetlands (NTW)
- Grasslands (GR)
- Deserts/Shrublands (D/S)
- Mountains (MT)
- Forests (FO)
- Unspecified (UN)



PANEL

- Dr. Lydia Olander, Nicholas Institute, Duke University
  - Measuring risk reduction effectiveness
- Dr. Todd Jones-Farrand, US Fish and Wildlife Service
  - Measuring effectiveness for biodiversity support
  - FWS work on metrics
- Dr. Vamsi Krishna Sridharan, Tetra Tech (& Emily Corwin)
  - Ideas for advancement in effectiveness data collection and integration with modeling
  - ASCE NBS work group for standards development and their need for effectiveness data
- Ms. Ellen Bolen, National Fish and Wildlife Foundation
  - Effectiveness data collected by NFWF and what they've learned from that data
  - Ideas for improving data collection on NBS given NFWF experience

New Project: Laying the groundwork for evaluating the effectiveness of NBS



Initial scope

Nature-based solutions:

- Coastal salt marsh and mangroves
- Inland watershed management (flood and drought, non-urban)

Alignment with USACE and ASCE

Project outcomes:

- **Risk reduction**
- Species/habitat benefits

Things we would like to understand (about NBS effectiveness in attenuating risks)

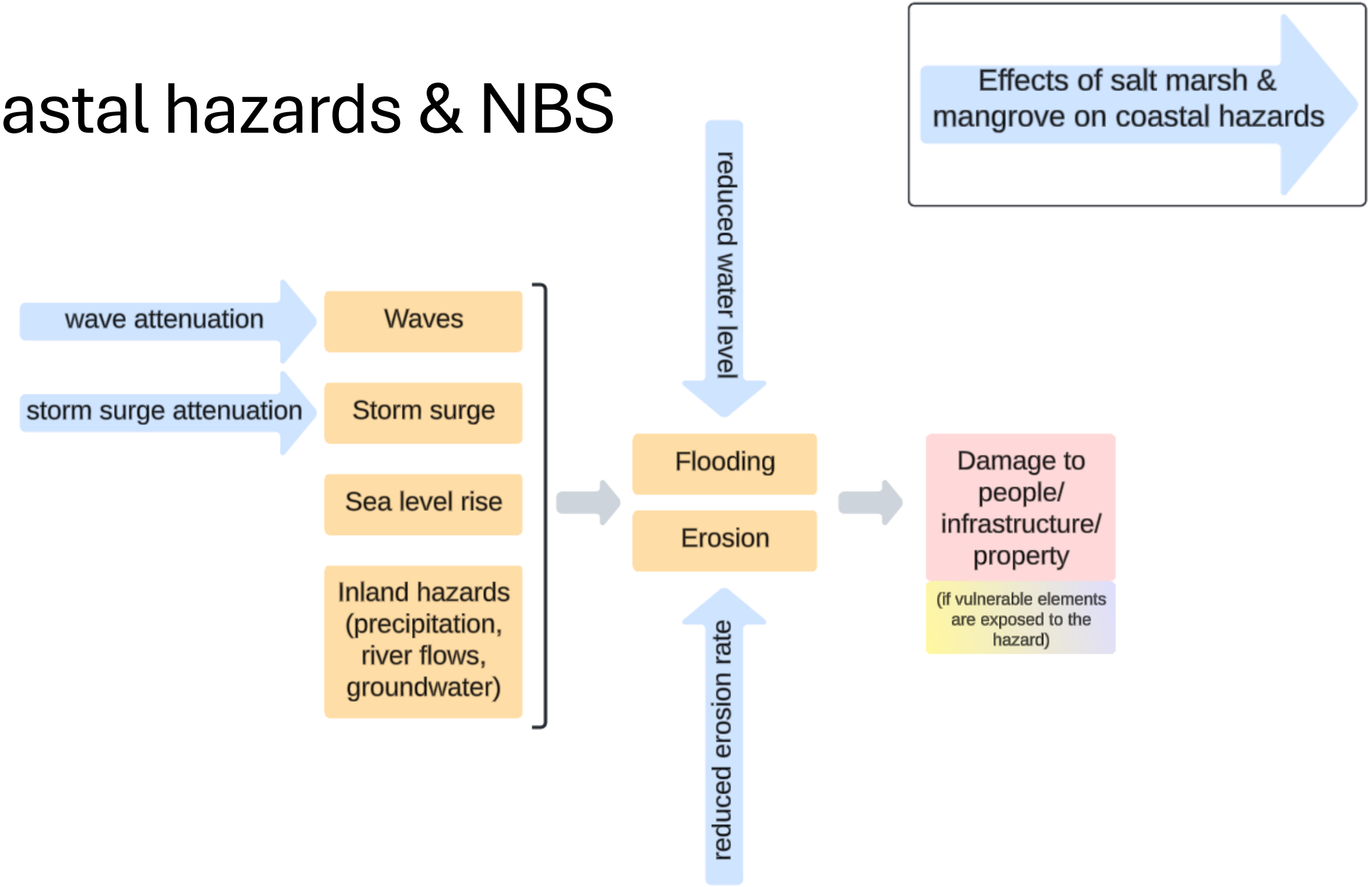
Our focus: NBS & hazard attenuation

- **How NBS changes the magnitude & frequency of relevant hazards (e.g., waves, water level, erosion)**
- NBS resistance (or fragility) to hazards
- How quickly and fully the NBS can recover after damage
- **How NBS project design influences these characteristics & relationships**

Requires additional risk modeling

- How NBS changes exposure and vulnerability of communities, infrastructure, and assets to the hazard
- Costs of damages avoided due to the NBS

Coastal hazards & NBS



(DRAFT) Metrics for measuring coastal hazard attenuation

Hazard attenuation elements	Metric	Measurement type
Wave attenuation	Incident significant wave height (under different hydrodynamic conditions, preconstruction and postconstruction)	Field (sensor)
	Transmitted significant wave height (under different hydrodynamic conditions, preconstruction and postconstruction)	
	Wave period offshore and inshore of NBS feature (preconstruction and postconstruction)	
Reduced water levels	Water level (at same location under similar hydrodynamic conditions, preconstruction and postconstruction)	Field (sensor, high water marks)
	Inundation extent around project site (under similar hydrodynamic conditions, preconstruction and postconstruction)	Remote sensing
Reduced erosion rate	Rate of shoreline position change over time (preconstruction and postconstruction)	Field or remote sensing

This list is not complete. Not all projects will measure all metrics.

(DRAFT) Metrics needed to run models of coastal hazard attenuation

Hazard attenuation elements	**Metric**	**Measurement type** (blue = potentially available from project design docs)	**Why you'd measure this**
Wave attenuation & Storm surge attenuation & Reduced water levels	Marsh boundary	Field or remote sensing	Input data to represent NBS vegetation in coastal hazard models
	Vegetation height	Field (survey)	
	Vegetation stem diameter		
	Vegetation stem density		
	Leaf area index (proxy for combination of vegetation height, diameter, and density)	Remote sensing	To evaluate utility of remotely sensed vegetation data to replace field-measured data in coastal hazard models
	Bathymetry & topography	Field or remote sensing	To calibrate & validate coastal hazard models for your site
	Water levels under different hydrodynamic conditions	Field (sensor)	
	Wave pressure under different hydrodynamic conditions		
	Hydrostatic pressure under different hydrodynamic conditions		
	Atmospheric pressure under different hydrodynamic conditions		

This list is not complete. Not all projects will measure all metrics.

(DRAFT) Additional characteristics of NBS relevant to coastal hazard attenuation

Metric	**Measurement type** (blue = potentially available from project design docs)
Marsh/mangrove dimensions (width, length, height)	Field or calculate from marsh boundary
Marsh platform slope	Field or calculate from topography
Channel width within marsh	Field or calculate from marsh boundary & topography
Channel density within marsh	
Channel depth within marsh	Field or calculate from bathymetry
Vegetation species	Field (survey)
Bathymetry & topography	Field or remote sensing

This list is not complete. Not all projects will measure all metrics.

Research gaps – NBS & coastal hazards

- Hazard attenuation by NBS in different settings
- Potential differences between natural & restored ecosystems
- Influence of plant species and structure on wave attenuation
- Quantifying conditions under which NBS are more/less effective for coastal hazard attenuation
- How quickly new NBS projects develop coastal hazard attenuation functionality
- Limits of ecosystem resilience & thresholds for failure
- Disturbance-recovery dynamics of NBS, especially under global change (SLR, increased storminess)

Blue = addressed to some extent by draft recommended metrics lists

Deliverables for Phase 1

Phase 1

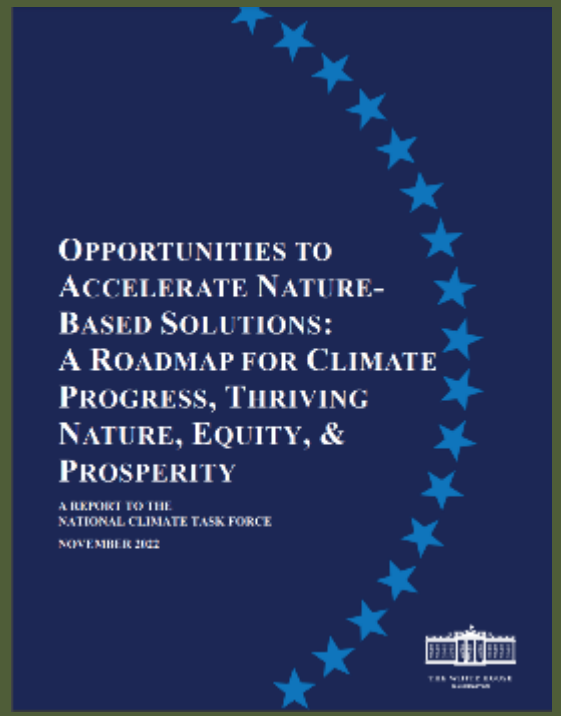
- Recommended metrics & measurement protocols
- Data collection template to facilitate alignment & sharing
- Prioritized research & knowledge gaps
- Network to collaborate on data collection & research

Development of Effectiveness Measures for Nature-based Solutions

Beth Stys, Skyler Shibuya, Jason Goldberg, Todd Jones-Farrand
USFWS

The White House NBS Roadmap

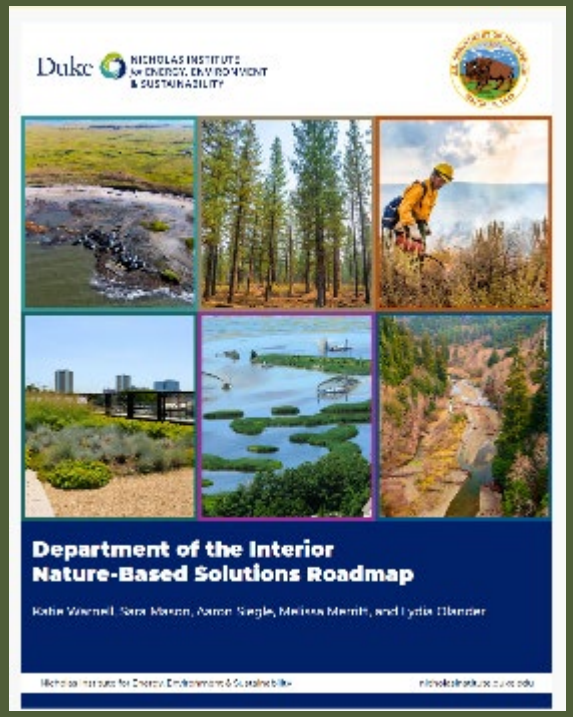
November 2022



"Agencies should also develop interagency best practices for **monitoring the full suite of benefits** from NBS, including how best to **measure and verify climate benefits.**"

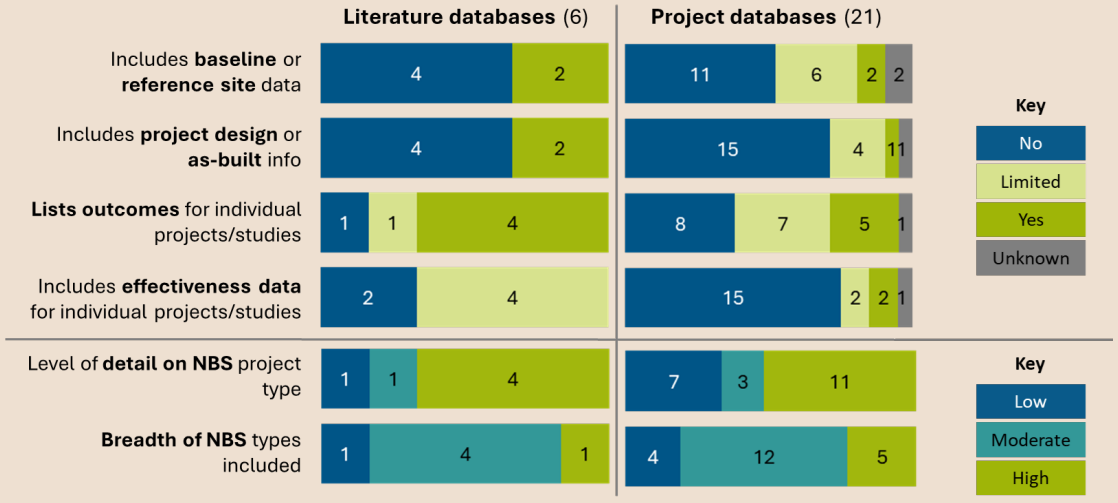
DOI NBS Roadmap

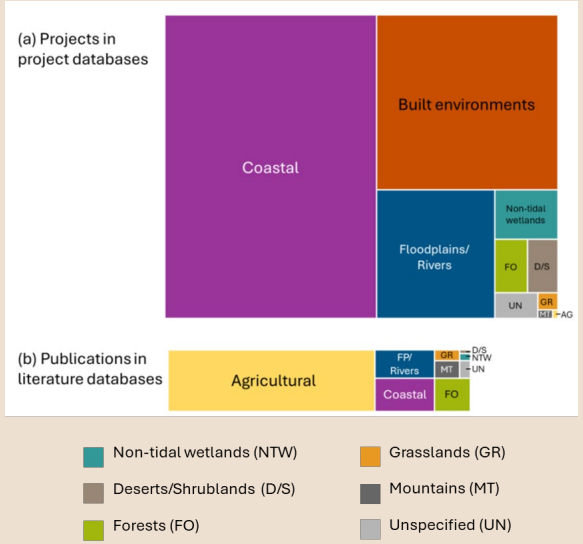
2023

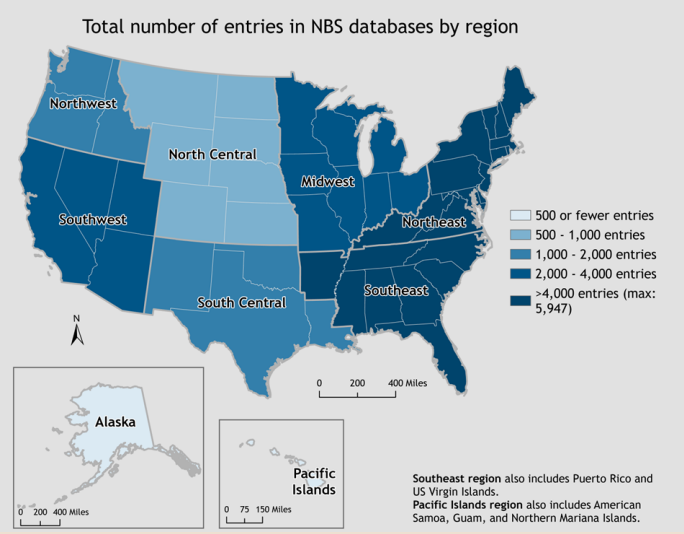


"Monitoring and evaluation of project performance using a **common set of credible metrics** is key to filling critical evidence gaps, providing information needed for adaptive management, and ensuring projects achieve **satisfactory and measurable results.**"

Do Metrics Exist → Not Really







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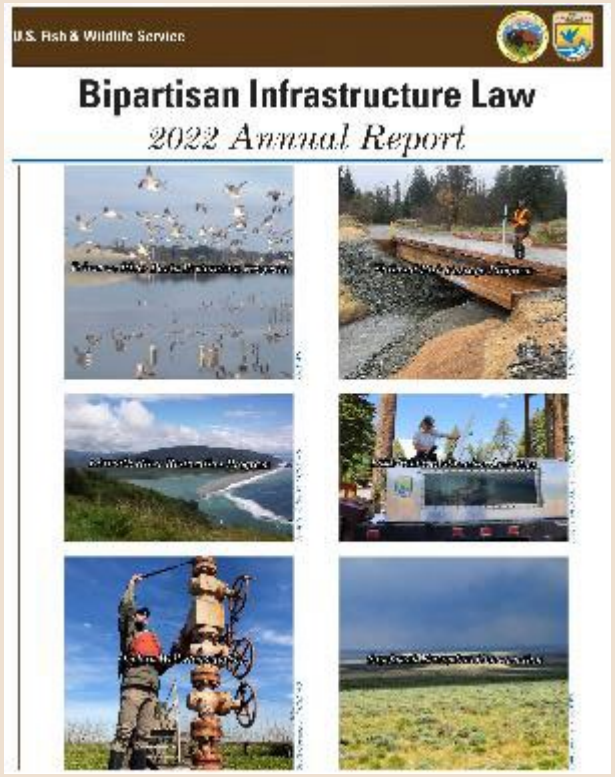


- Bipartisan Infrastructure Law - BIL
- Inflation Reduction Act - IRA
- DOI Coordinated Program for Resilience and Environment (CPRE)
  - DOI Evaluation Monitoring Measurement and Metric NbS sub-workgroup (EM3)
- US Global Change Research Program – USGCRP
  - Federal Adaptation and Resilience Group – FARG

NBS in the FWS

- Nature-based Resiliency Coordinator, Sara Ward
- NBS workgroup in FWS
- Phase 2 - DOI NBS Roadmap with Duke University

2024
Nature-Based Solutions
Effectiveness Measures
Guidance Document

CHALLENGES

- Definitions
- Types of Measures
- Scale
  - Scope of Project
  - Level of reporting
  - More variables to measure
- Time
  - Long-time periods
  - Tied to funding cycles
- Shifting Baseline
- Uncertainty

Biodiversity Needs Definition

- Issues with the Term
  - Dependent on place (e.g., ecosystem type) & setting (e.g., ecoregion)
  - Dependent on scale of measurement (e.g., ecosystem type to landscape)
- Issues with Measurement
  - Different taxa groups & species are better suited to different protocols
  - Multiple ways to measure (e.g., presence, occupancy, demography)
    - Variable costs & knowledge benefits lead to complicated tradeoffs
  - Changes with time since restoration (e.g., planted forest vs. mature)

Biodiversity strategy for 2030

Read about the EU's biodiversity strategy for 2030 - our ambitious and long-term plan to protect nature and reverse the degradation of ecosystems.

GOV.UK

Home > Environment > Wildlife, animals, biodiversity and ecosystems > Biodiversity and ecosystems

Guidance

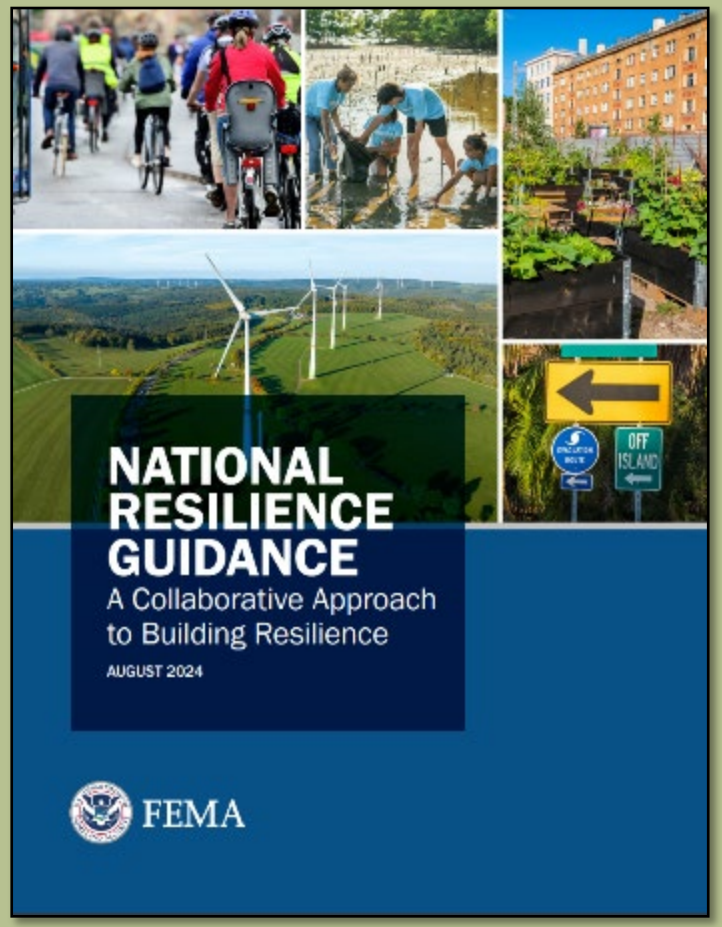
Calculate biodiversity value with the statutory biodiversity metric

When and how to measure a habitat or development's impact on biodiversity.

From: Department for Environment, Food & Rural Affairs

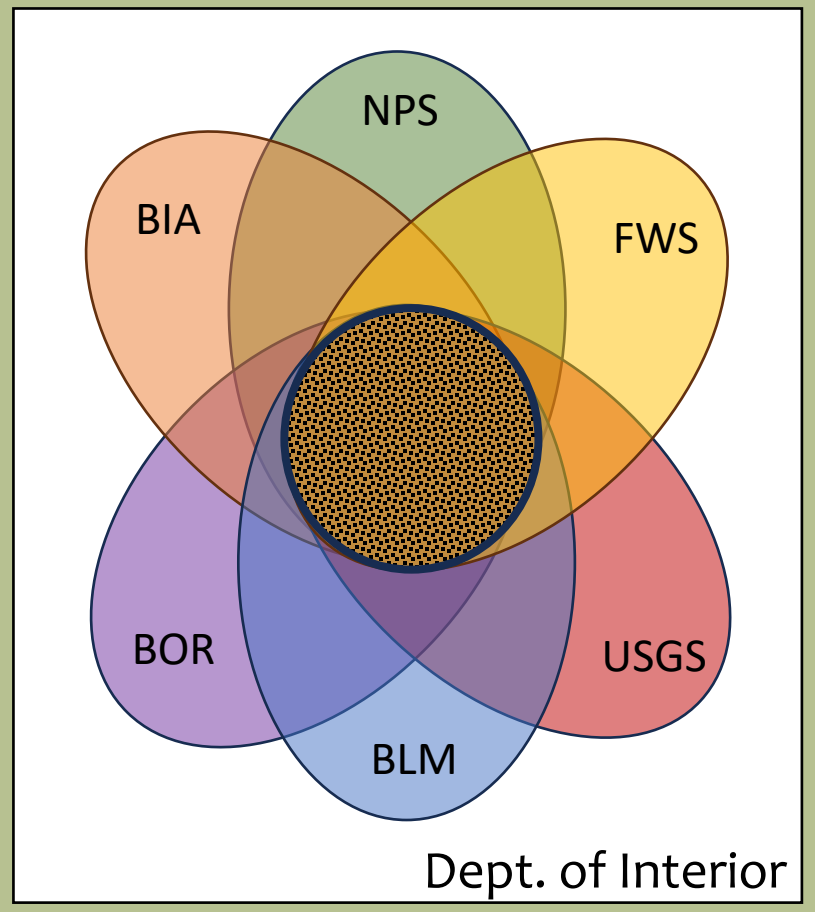
Published 7 July 2021

Last updated 27 February 2024 — See all updates



Type	Focus	Examples
Input	The number of resources being put into the effort	
Process	The activities being performed	
Output	The products or services produced by the effort	
Outcome	The impact from the effort	

Scale of Reporting



Department-level Metrics

Bureau-level Metrics

Project-level Metrics

Action-level Metrics

Identifying Metrics

NbS

Reduces

Hazard

Reduces

Exposure + Sensitivity + Adaptive Capacity

Reduces

Risk of Damage

Biodiversity Vulnerability

Impacts

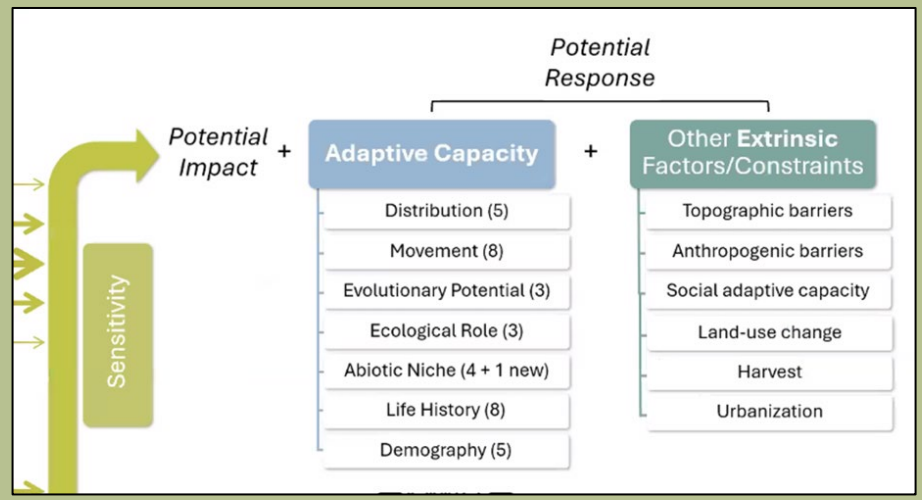
Influence

Influence

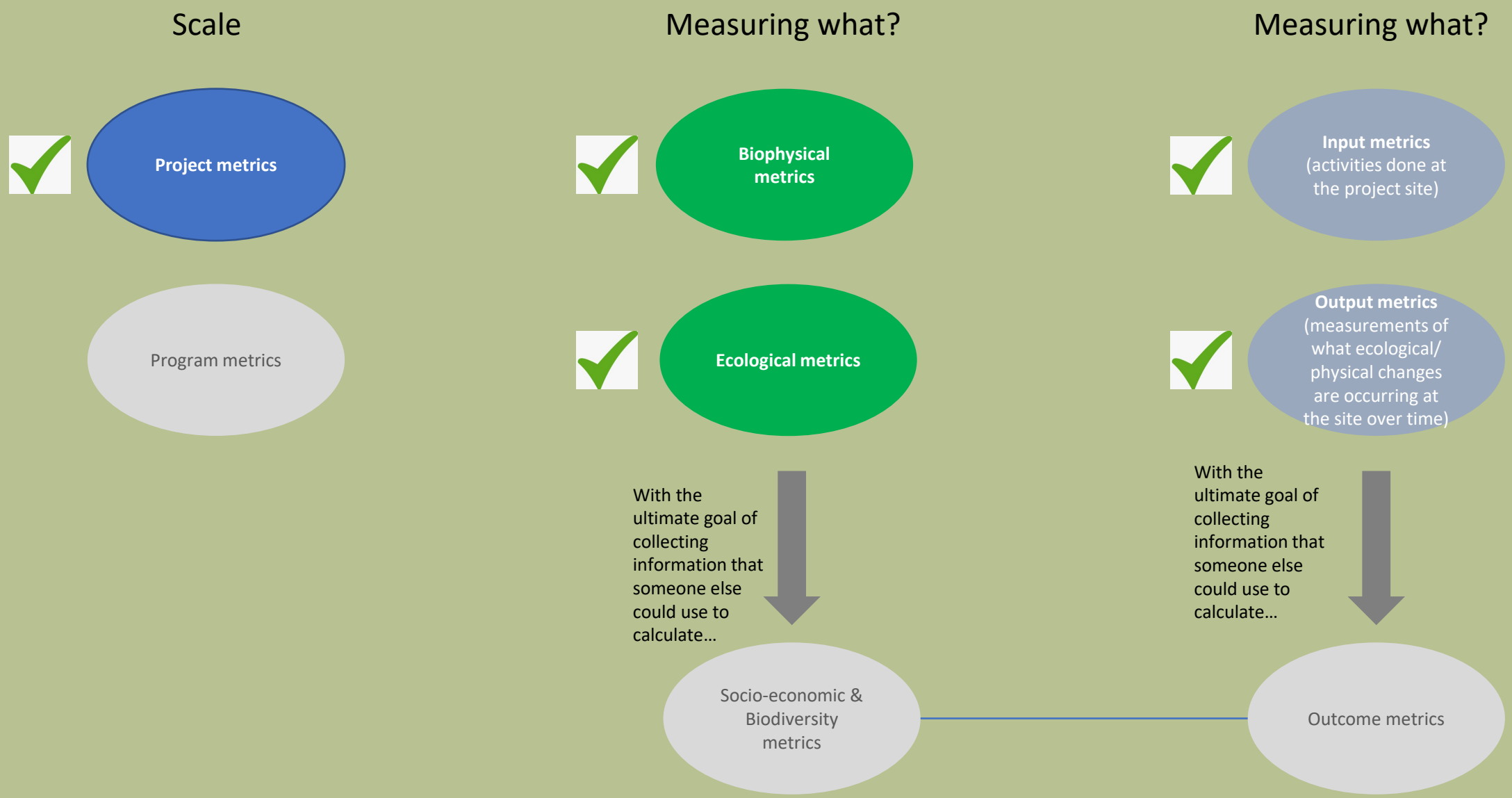
Restoration Plan & Design

Project Inputs

Project Implementation



What type of metrics are we talking about?



Early Prototype species/habitat metrics list

Purpose	**Metric**	**Measurement type** (blue = potentially available from project design docs)
Project information	Specific habitat system being recreated, restored, or enhanced	Project design docs
	Problem being addressed	
	Specific NBS action taken	
	Project size	
Habitat quality	Naturalness of project site	Project design docs (targets), field measurement
	Vegetation diversity & structure	
	Water depth, duration, & flow	
	Chemical composition at outlet	
	Habitat connectivity	Spatial data analysis, informed by project design docs
Biodiversity benefits	Presence & abundance of desired species (indicators for functioning ecosystem)	Field measurement to build or evaluate models
	Presence & abundance of undesirable species	
	Multi-species index measures (e.g., Index of Biotic Integrity, Shannon-Weaver Diversity)	

Draft Spectrum of Project-level Assessment Rigor

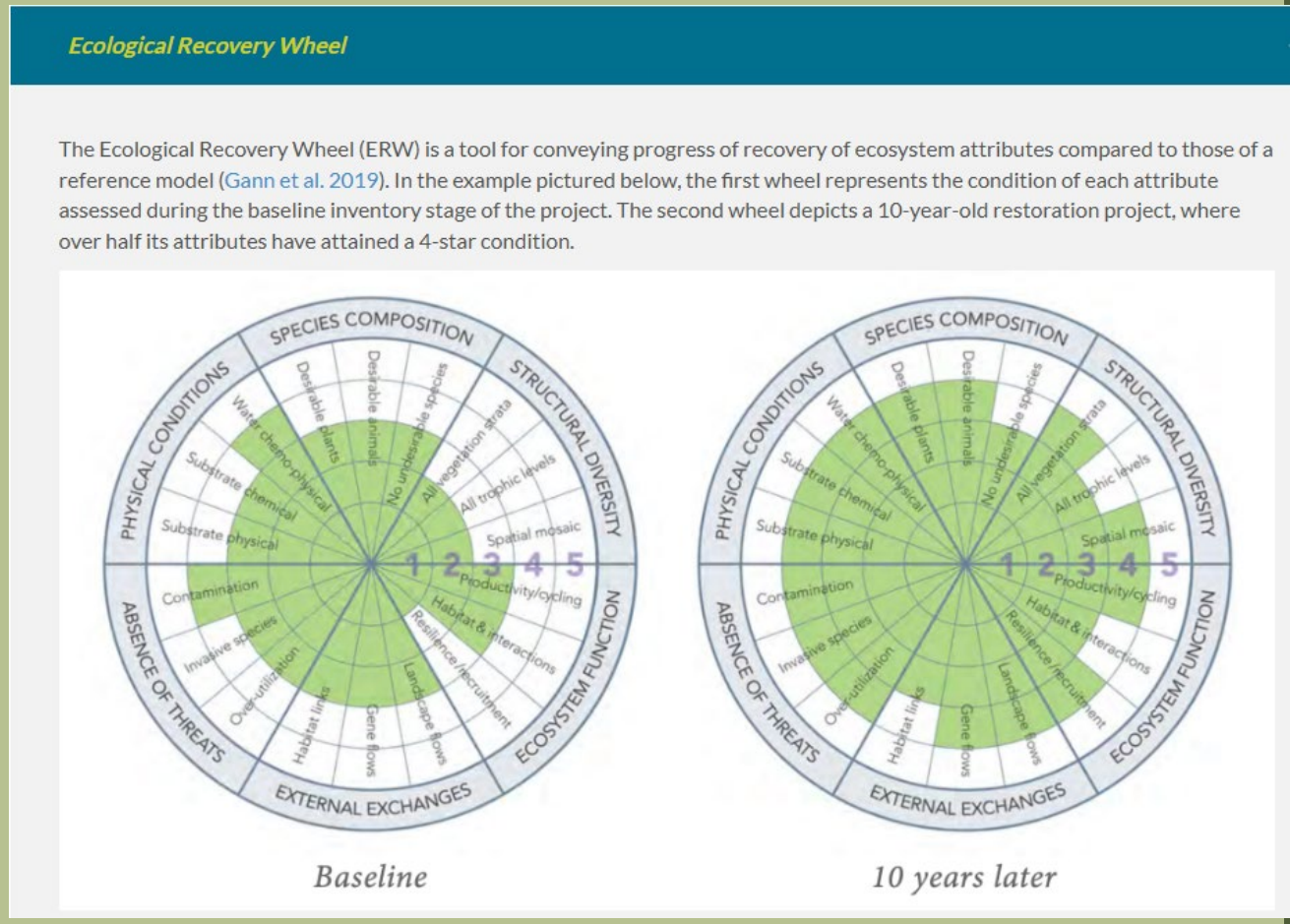
Metric Class	Minimum Criteria
Intent	Clearly documented Theory of Change (Doing X expecting Y)
Input	$$, People hours
Process	Milestones completed
Output	Acres or Miles of Ecosystem
Short-term Outcomes	Restoration success metrics (e.g. plant survival)
Long-term Outcomes	Biodiversity Index + Invasive Species Index

Modeled Outcomes

Comprehensive Criteria
Specific SMART Objectives for all Key Attributes
$$, People hours
Milestones completed
Metrics of Ecosystem Structure, Connectivity & Function
Change in habitat amount, condition, configuration, regimes, & connectivity
Change in biodiversity (e.g., Shannon-Weaver Index) across multiple taxonomic groups

Draft Recommendation: Standardize Categories not Individual Metrics

- What are the general categories of metrics we need for biodiversity assessment?
  - Habitat Type
  - Habitat Condition
  - Target Species Persistence
  - Invasive Species
  - Change in Resilience
- Standardization categories promotes “role up”



https://www.ser.org/page/Standards-Tools

Want to join us?

We will be hosting a virtual workshop winter 2025 to discuss the proposed biodiversity metrics framework, if you'd like to be a part of that conversation please email david_jones-farrand@fws.gov

Thank you!

david_jones-farrand@fws.gov

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SOUTHEAST
Climate Adaptation Science Center

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DEPARTMENT OF THE INTERIOR

TETRA TECH

The Need for Metrics to Objectively Evaluate the Why, Who, Where, What, When, and How of Nature-Based Solutions

Vamsi Krishna Sridharan

December 12, 2024

ACES
A Community on Ecosystem Services™

The Nature-based Solution Life Cycle

TETRA TECH

2. **Who** are the concerned parties involved?

4. **What** are the cost-benefit considerations?

1. **Why** implement NbS?

3. **Where** do we implement the NbS?

5. **When** will the NbS mature?

6. **How** will the implementation and adaptive management occur?

Image credits:

1. Brickell Bay resiliency improvement: https://www.miami.gov/My-Government/Departments/Office-of-Capital-Improvements/Capital-Improvements-Projects-Construction-Notices-Per-District/District-2-Capital-Improvements-Projects-1-1/Brickell-Bay-Drive-Seawall-Resiliency-Improvements
2. Crisfield FEMA-MDEM stakeholder engagement: https://www.fema.gov/press-release/20240228/fema-and-mdem-highlight-crisfield-mds-commitment-reducing-flood-risk-tour
3. Crisfield climate resilience partnership: https://www.nature.org/en-us/newsroom/resilient-crisfield-maryland/
4. Sassafras Landing living shoreline demonstration: https://wmap.blogs.delaware.gov/2019/09/16/sassafras-landing-a-living-shoreline-demonstration/
5. Oyster castles on the James River: https://thejamesriver.org/living-shoreline-collaborative-partner-highlight-shereen-hughes/
6. Retired Cranberry Bog restoration: https://today.uconn.edu/2022/02/digging-into-the-finer-details-of-retired-cranberry-bog-restorations/#

Performance metrics rollup to participant requirements

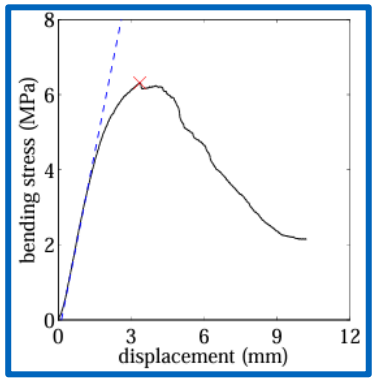

Image credtis:

1. Stem breakage of Spartina grass: Vuik et al. 2017
2. How marsh grass protects shorelines (2021): https://news.mit.edu/2021/how-marsh-grass-protects-shorelines-1018
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4. Marsh resilience to hurricanes: Mo et al. (2020)

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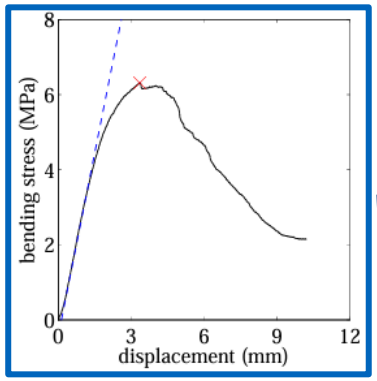

"If you put the stiffest plants at the edge, they might not survive, because they're feeling very high wave forces. By describing why Mother Nature organizes plants in this way, we can hopefully design a more sustainable restoration" – Heidi Nepf, MIT

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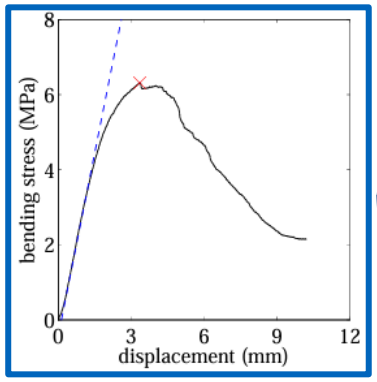

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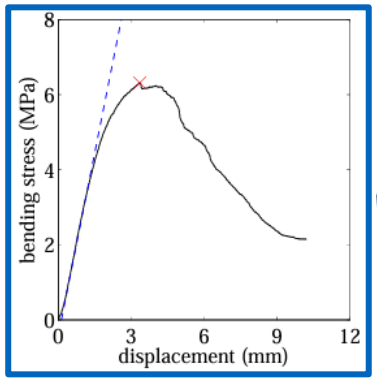

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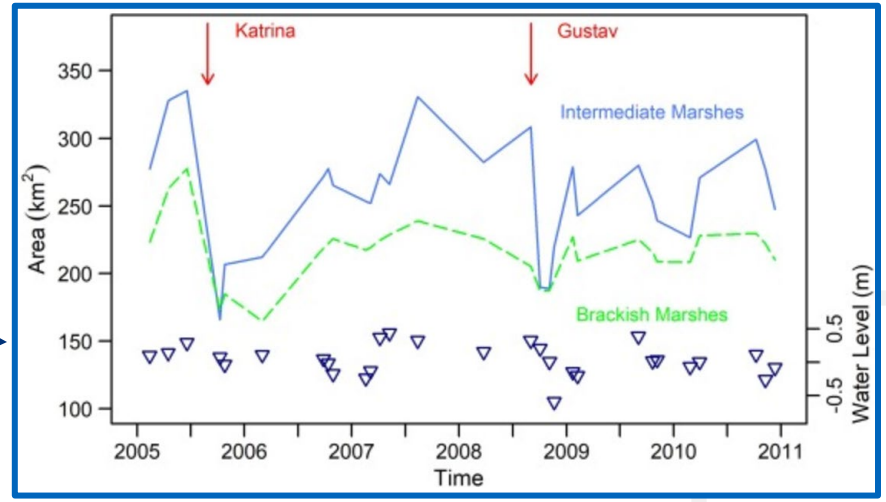

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Science rolls up to meet technical needs

Structural performance

Ecological improvements

Habitat improvement

Species richness

Socioeconomic benefits

Science rolls up to meet technical needs

Structural performance
Ecological improvements
Habitat improvement
Species richness
Socioeconomic benefits

Engineering performance
Ecosystem cobenefits
Benefits accounting
Resilience objectives
Risk reduction

Metrics to Evaluate

Engineering performance: wave attenuation, surge protection, erosion control, SLR defense

Ecosystem cobenefits: economic, social, cultural, ecological, environmental

Return-on-investment: project cost, improvements over lifetime, premiums reduced

Risk mitigation: infrastructure protected, lives saved, disruptions avoided

Metric Evaluation Approaches

TETRA TECH


Scientific literature to understand processes and develop designs


Expert elicitation to understand priorities and approaches


Post-implementation monitoring of ecosystem and performance


Stakeholder engagement tools to elicit benefit-cost considerations


Risk evaluation and management to understand and mitigate threats


GIS data synthesis over time to determine socioeconomic impacts


Computer and physical simulations to understand processes and project the future


Remote sensing and in-situ environmental and ecosystem condition

AI/ML tools to synthesize big data and generate insights

Metric rollup evaluation pathway

Where will understanding of how to roll-up local-scale metrics to technical needs come from?

Metric rollup evaluation pathway

- Best Professional Judgement
- Monitoring and anecdotal evidence
- Expert elicitation
- Mental mapping
- Science integration and synthesis

Basic → **Advanced** → **State-of-the-art** → **Cutting-edge**

Metric rollup evaluation pathway

- Best Professional Judgement
- Monitoring and anecdotal evidence
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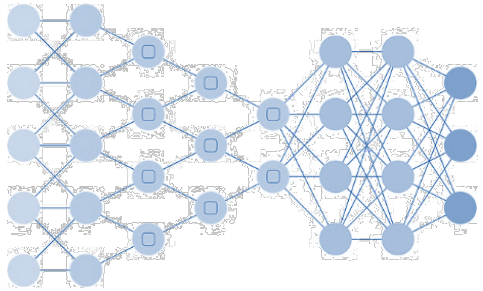
- Mental mapping
- Science integration and synthesis

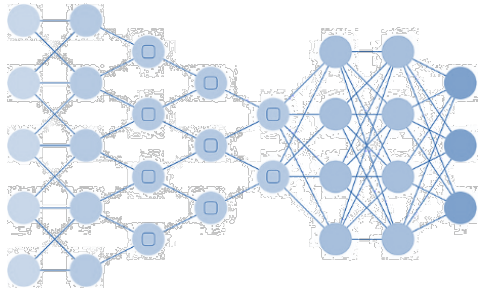


Basic → **Advanced** → **State-of-the-art** → **Cutting-edge**

AI/ML- and advanced statistics-based phenomenological linkages and scaling

Metric rollup evaluation pathway

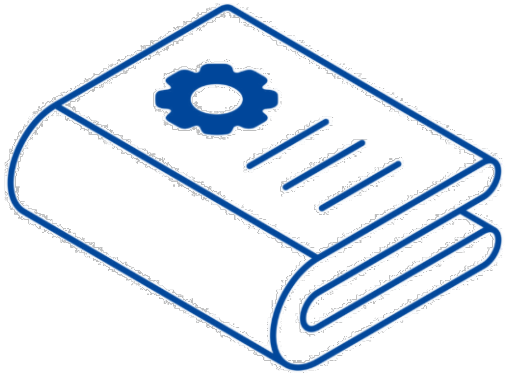
- Best Professional Judgement
- Monitoring and anecdotal evidence
- Expert elicitation
- Mental mapping
- Science integration and synthesis



- Analysis and design theory
- Technical guidance
- Standards and manuals

Basic → **Advanced** → **State-of-the-art** → **Cutting-edge**

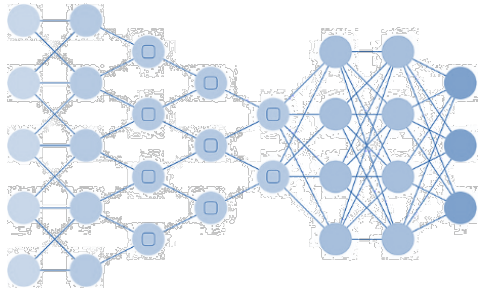
AI/ML- and advanced statistics-based phenomenological linkages and scaling



Metric rollup evaluation pathway

TETRA TECH

- Best Professional Judgement
- Monitoring and anecdotal evidence
- Expert elicitation
- Mental mapping
- Science integration and synthesis



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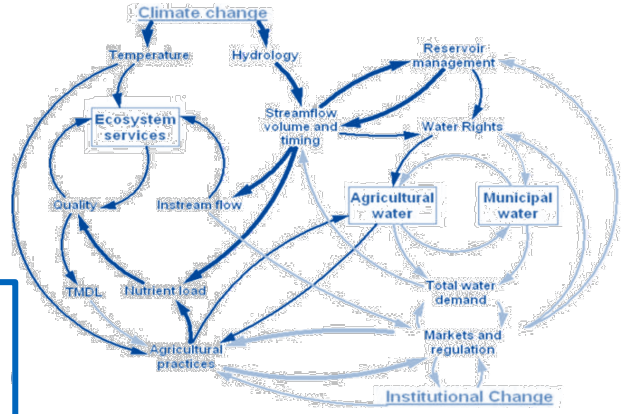

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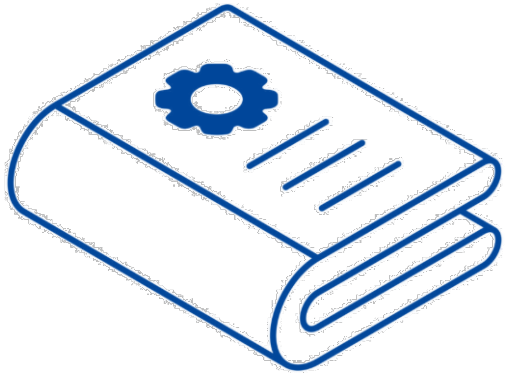
AI/ML- and advanced statistics-based phenomenological linkages and scaling



- Agent-based models
- State-space models
- Structured dynamic models
- Probabilistic graphical models
- Process-based models
- System-of-systems models

Questions?

Vamsi Krishna Sridharan, Ph.D., M.ASCE
Fairfax, VA
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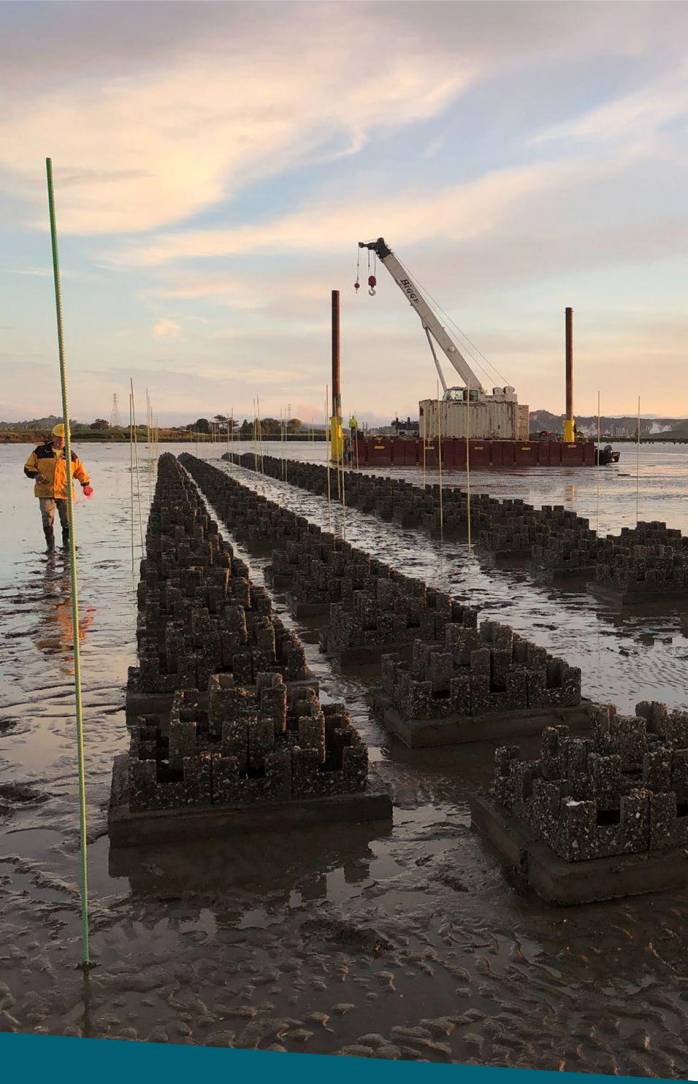
(650) 862-2658



Construction of nearshore oyster reefs at the SF Bay Living Shorelines Project at Giant Marsh, May 2019 at low tide per permits. Photo by Triton Marine.

ASCE Nature-based Solutions Task Force

December 12, 2024

ASCE | INFRASTRUCTURE RESILIENCE

COPRI ASCE

SEI ASCE

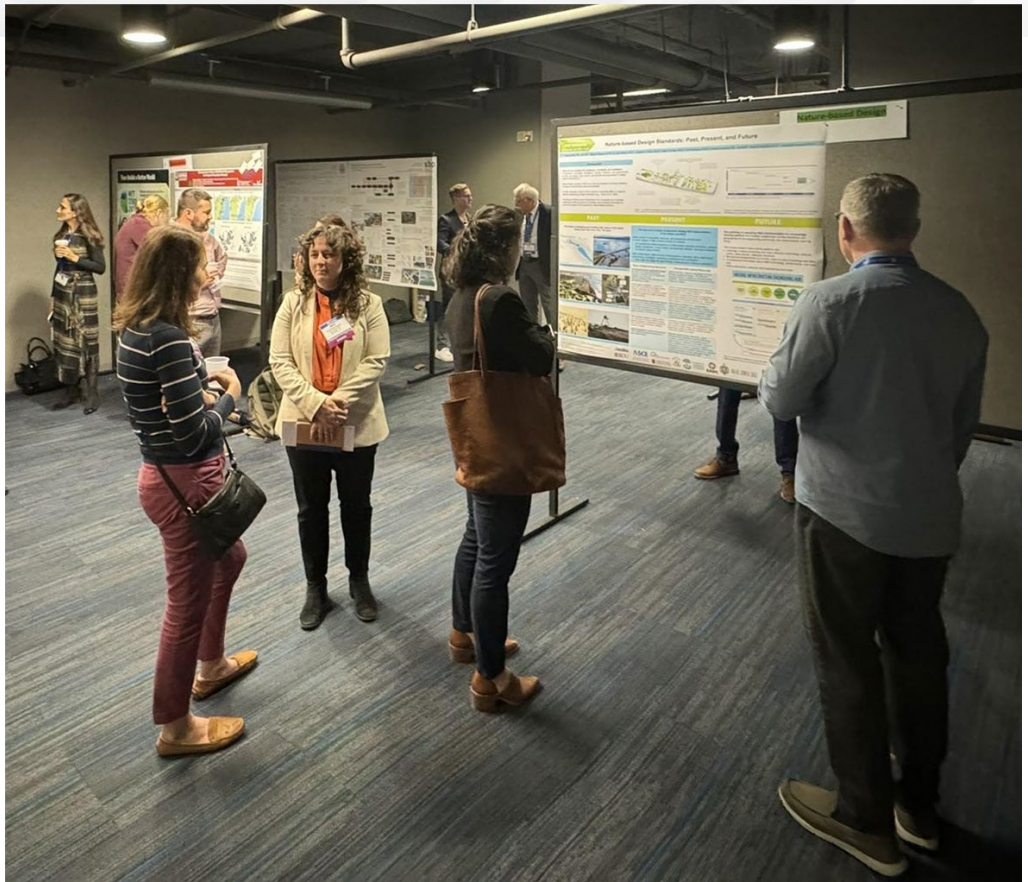
EWRI ASCE

ASCE | CLIMATE ADAPTATION

ASCE NbS Task Force
Origin Story

ASCE NbS Task Force Origin Story

ASCE 2023 CONFERENCE
INSPIRE
INFRASTRUCTURE INNOVATION & ADAPTATION FOR A SUSTAINABLE & RESILIENT WORLD
ARLINGTON, VIRGINIA | NOV. 16-18, 2023

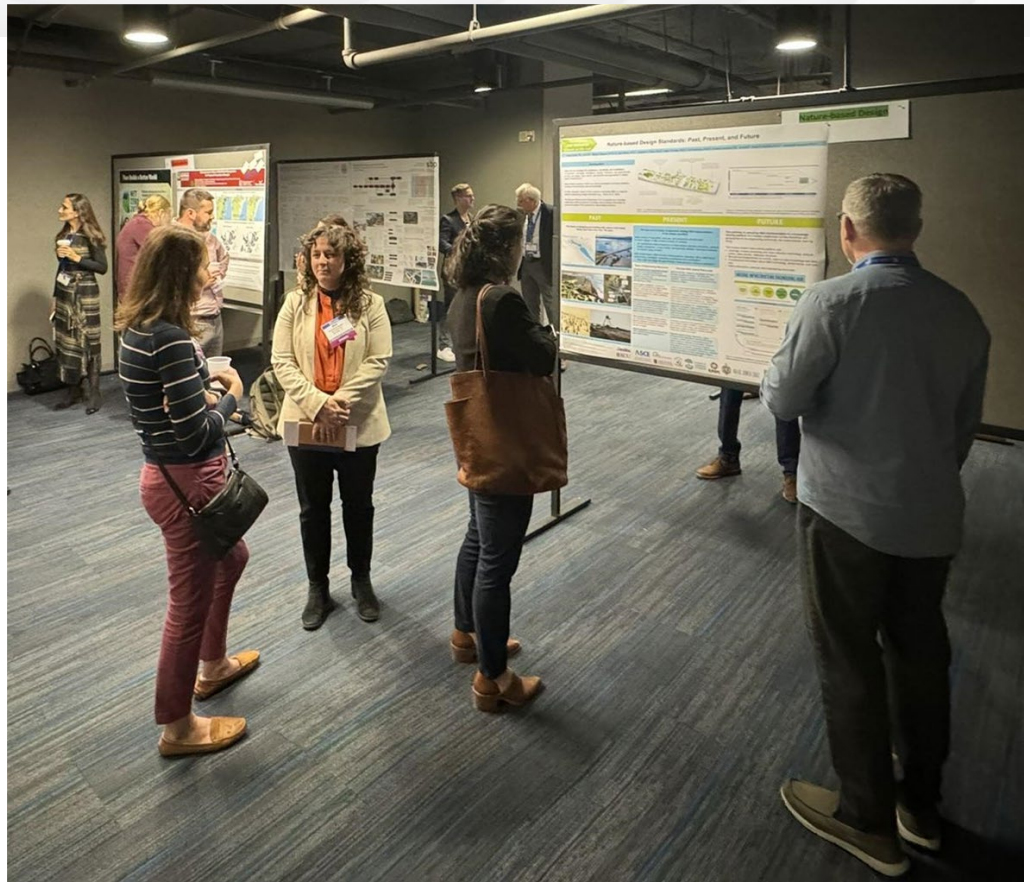


ASCE NbS Task Force Origin Story

ASCE 2023 CONFERENCE
INSPIRE
INFRASTRUCTURE INNOVATION & ADAPTATION FOR A SUSTAINABLE & RESILIENT WORLD
ARLINGTON, VIRGINIA | NOV. 16-18, 2023

Nature-based Solutions Workshop

Participants were asked to assist the profession in closing the gap on much needed nature-based solutions (NbS) engineering guidance



ASCE hierarchy of publications

ASCE’s First-Ever Nature-based Solutions Manual of Practice

ASCE's First-Ever Nature-based Solutions Manual of Practice

ASCE's First-Ever Nature-based Solutions Manual of Practice

Part 1:
General Guidance

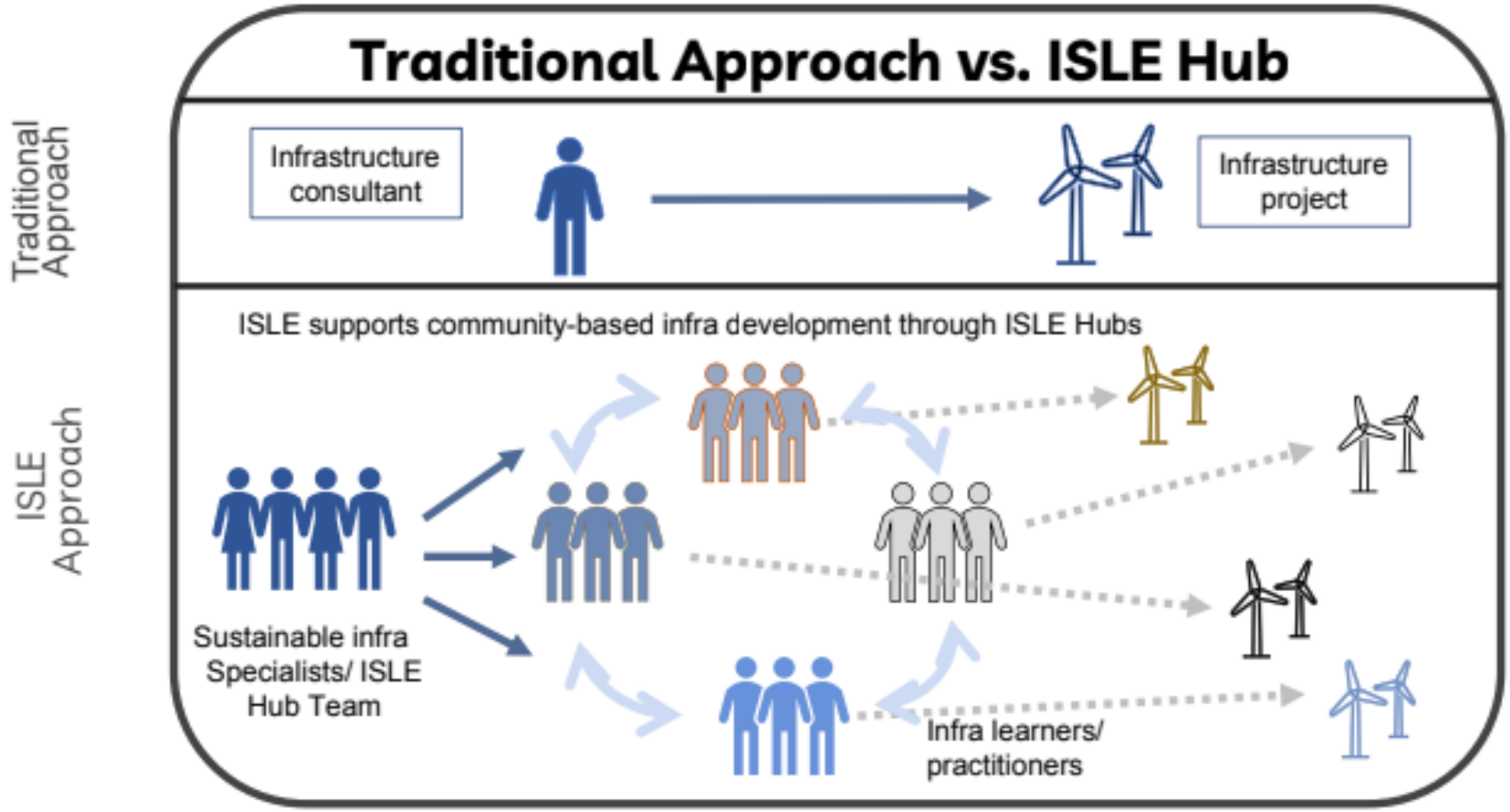
ASCE's First-Ever Nature-based Solutions Manual of Practice

Part 1:
General Guidance

Part 2:
Technical Appendices
Design and Constructability Guidance for Specific Types of NbS

Forum for NbS Guidance Writers to Collaborate

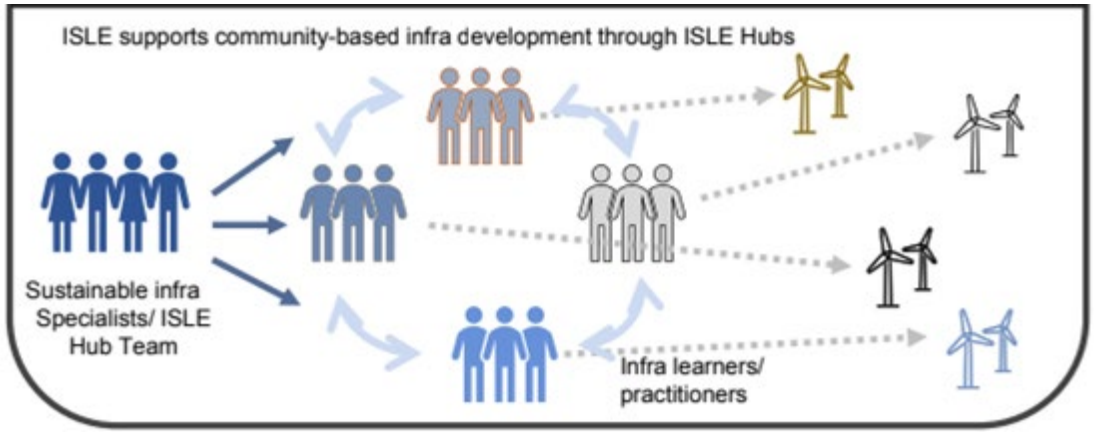
Forum for NbS Guidance Writers to Collaborate



TRANSLATING MODEL
ISLe Virtual Learning Hubs

The ISLE Networks follow the ECHO model building capacity by bringing together infrastructure practitioners and experts to share knowledge and problem solve collectively.

Participation in ISLe Hub in 2025?



ASCE
ISLe Hub
For NbS Guidance
Writers

- Others?
- University of Maryland MoP (funded by Millenium Challenge Corporation)
- Army Corp of Engineers
- Oregon State (D. Cox, K. Ostrow, T. Tomiczek)
- Arctic Community of Practice (ColdCOP)
- SF[a] and MDC[b] Living Shorelines Guidance ([a]CA Coastal Conservancy, [b]Tetra Tech)

Task Force Goals

- Peer-reviewed article on the necessary engineering resources needed to standardize NbS practice by 2024
- **ISLe ASCE Hub** for NbS beginning 2025
  - Workshops
  - Webinars
  - National network of experts
- Special collection on NbS design standards and best practices
- **ASCE Manual of Practice** for NbSs
  - General guidance
  - Technical
- **ASCE Standards** for NbSs

Questions?

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Vamsi Krishna Sridharan, Ph.D., M.ASCE
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Coastal Resilience Dashboard

Program Overview

About the Data

This dashboard shows grantee-reported data, including projected values for projects in progress and actual values for completed projects. Data from active projects are subject to change and may not reflect the current status of restoration activities. The map will display multiple points for an individual grant if project sites are more than 20 miles apart.

Data accurate as of 6/12/24

Filters: (x)

Resilience Activity ×

× Marsh Restoration

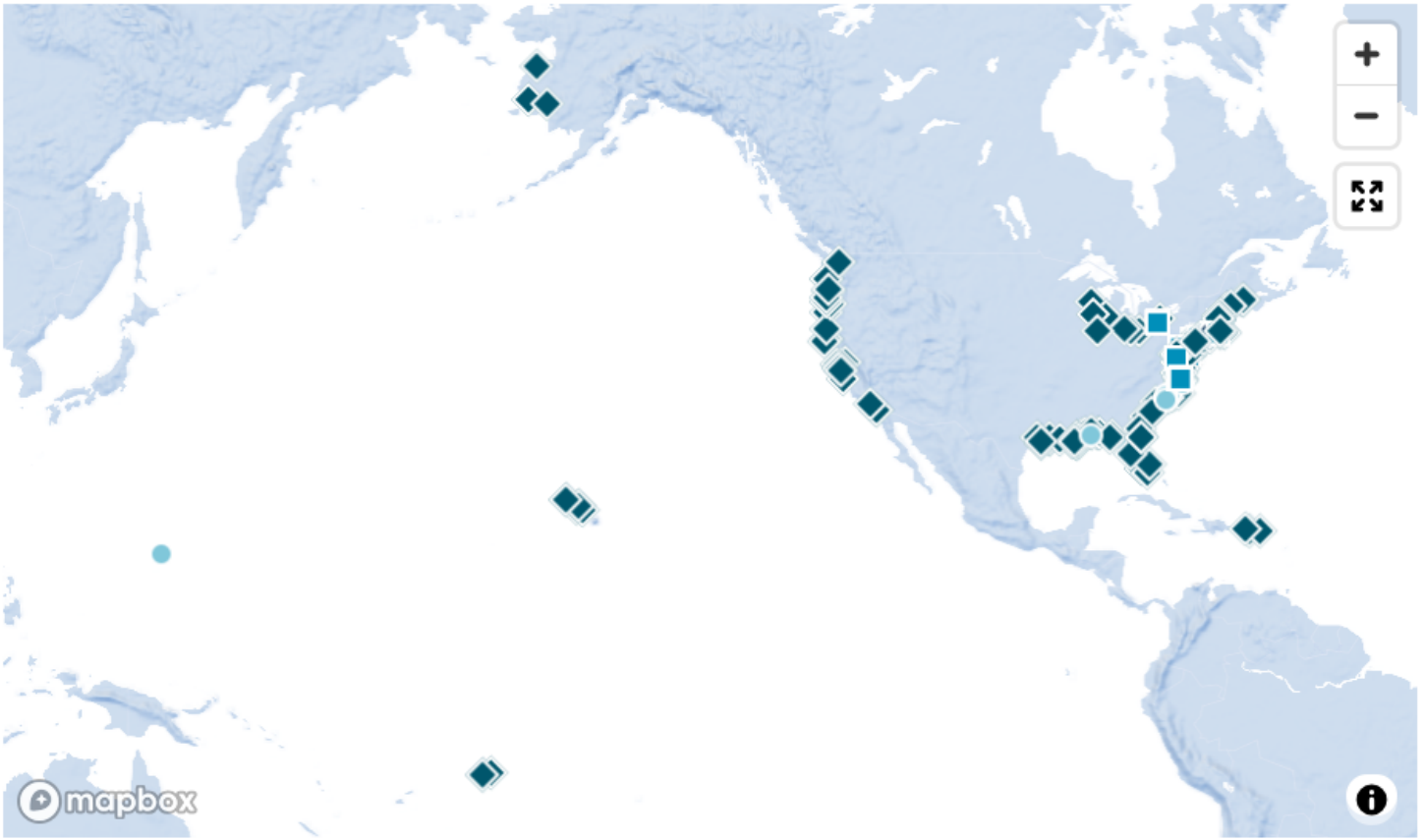
Select a filter

Data Type:

(•) All ( ) Final Only

Export to CSV

Data accurate as of 6/12/24



Choose a point on the map above to view details on a project

Filters:

Resilience Activity ×

× Marsh Restoration

Select a filter

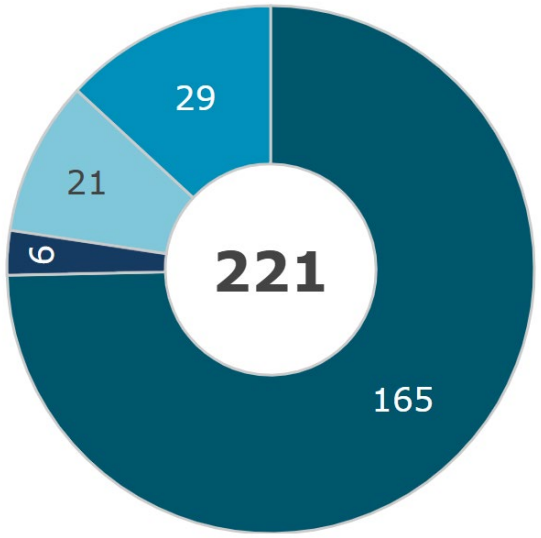
Data Type:

◉ All ○ Final Only

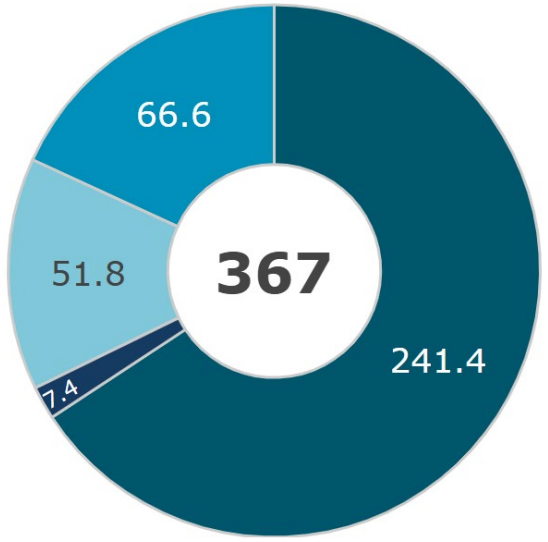
Export to CSV

Data accurate as of 6/12/24

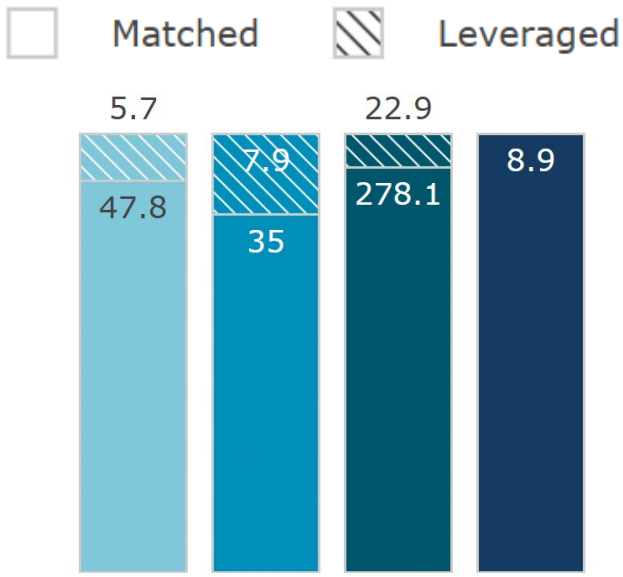
Grants Awarded



Funds Awarded ($Millions)

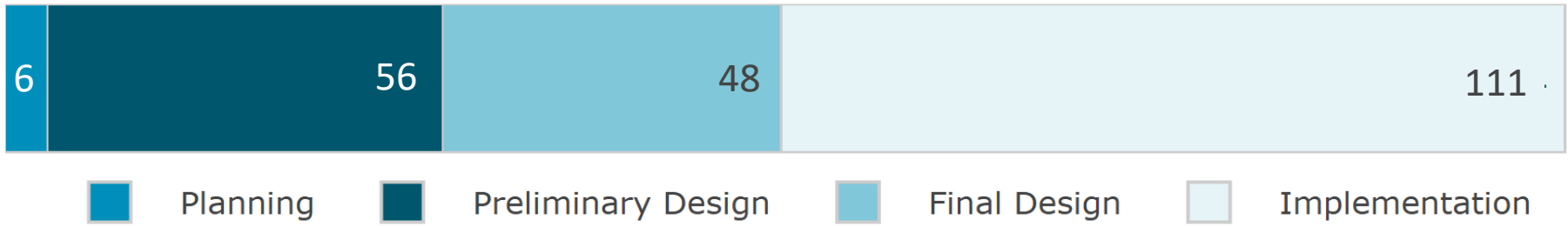


Matched and Leveraged Funds ($Millions)



National Coastal Resilience Fund
Emergency Coastal Resilience Fund
Hurricane Sandy Coastal Resiliency Competitive Grants Program
Sandy-NCRF Co-Funded

Grants Types



Filters:

Resilience Activity ×

× Marsh Restoration

Select a filter

Data Type:

◉ All ○ Final Only

Export to CSV

Data accurate as of 6/12/24

Ecological Highlights

(# Grants) refers to the number of grants contributing to each metric.

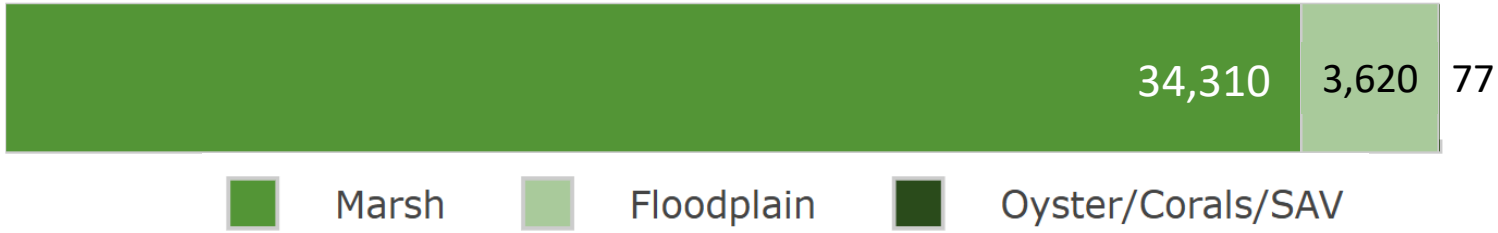
Click to see details of contributing grants.

About the Ecological Data

Data on species benefitting come from NFWF's Regional Coastal Resilience Assessments based upon an evaluation of habitats that could support species of conservation concern. Data on percent change in biomass and abundance come from monitoring data uploaded to NFWF's Coastal Resilience Open Data Platform.

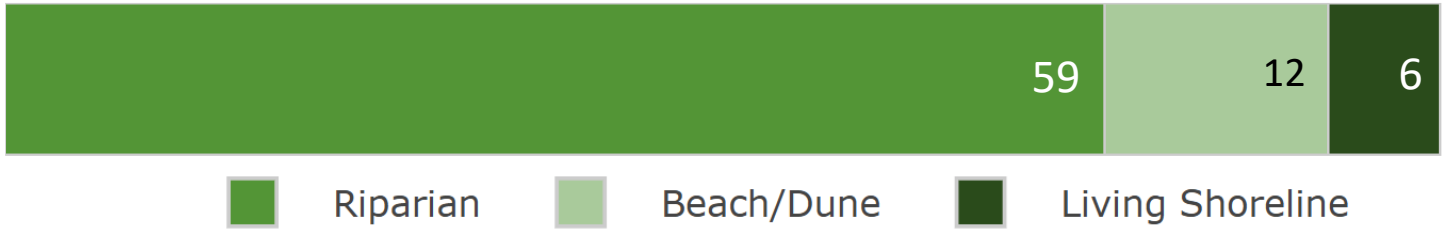
Acres Restored (106 Grants)

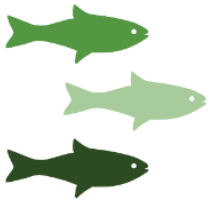
38,007 Acres



Miles Restored & Created (39 Grants)

77 Miles





Barriers to Fish Passage Removed (8 Grants)

18

Stream Miles Opened (8 Grants)

27

Filters:

Resilience Activity ×

× Marsh Restoration

Select a filter

Data Type:

(•) All ( ) Final Only

Export to CSV

Data accurate as of 6/12/24

Socioeconomic Highlights

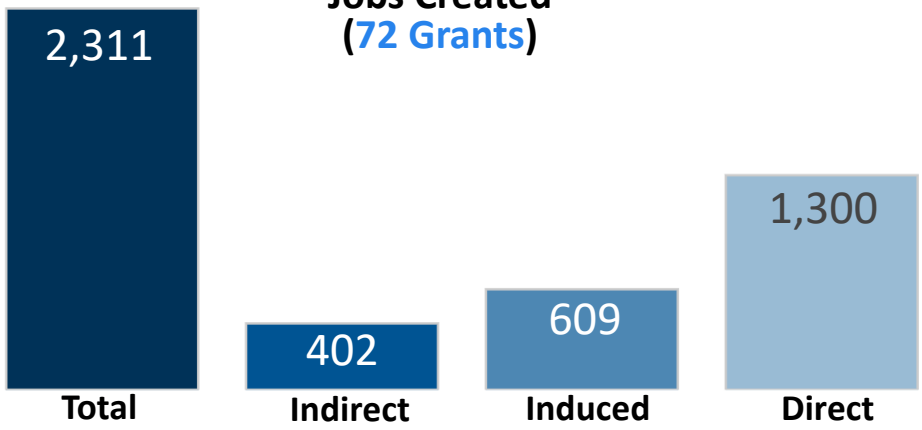
(# Grants) refers to the number of grants contributing to each metric.

Click to see details of contributing grants.

About the Socioeconomic Data

This data is developed from a contractor-ed assessment of the socioeconomic benefits on a subset of NFWF-funded coastal resilience projects and NFWF's obs calculator.

Jobs Created (72 Grants)



Grants Engaging Underserved Communities (68 Grants)

68
Grants Awarded

$146.9M
Funds Awarded

Properties Benefitting from Enhanced Protection (17 Grants)

4,978

Residential	4,765
Commercial	184
Public	16
Critical Infrastructure	13

Avoided Property Damage & Reduced Repairs ($Millions) (18 Grants)