EVALUATING COASTAL NATURE-BASED SOLUTIONS USING THE NBS EFFECTIVENESS DATA EXCHANGE

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COASTAL MANGROVES AND SALT MARSH

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About the NBS Effectiveness Data Exchange

The NBS Effectiveness Data Exchange is a proposed network of funders, practitioners, researchers, and data users that aims to promote consistent collection, submission, and use of relevant metrics for evaluating the effectiveness of nature-based solutions (NBS) projects. It plans to host the NBS Effectiveness Database, containing metrics related to NBS project design, ecological performance, local conditions, and critical outcomes to enable robust, large-scale evaluation of NBS effectiveness.

What Is in This Document?

1. Instructions for using the metrics list
2. A recommended list of metrics
3. An example data-sharing template
4. Background on how the metrics were developed

It also includes context about why this information is needed, including a list of research questions that could be better addressed with more consistent data collection and a list of quantitative coastal hazard attenuation models that use certain recommended metrics as inputs or for calibration. A spreadsheet with the full list of metrics including resources for measurement guidance is available on request.

This resource was created by the Nature-Based Solutions Effectiveness Data Project. This project represents a partnership between the Nicholas Institute for Energy, Environment & Sustainability at Duke University and the US Fish and Wildlife Service with funding from the Southeast Climate Adaptation Science Center. To learn more about the project, visit our website: https://nicholasinstitute.duke.edu/project/nature-based-solutions-effectiveness-data.

WHAT TYPES OF COASTAL NATURE-BASED SOLUTIONS AND OUTCOMES ARE COVERED?

The metrics list is relevant for **salt marsh and mangrove creation or restoration**, **hydrologic restoration of coastal wetlands**, and **living shorelines**.

Metrics were developed for two focal outcomes: **coastal hazard attenuation (waves, flooding, and erosion)** and **biodiversity support**. However, many of the metrics relate to project design and ecological function and are likely relevant to additional outcomes, which will simplify expanding the framework to cover those additional outcomes in the future.

HOW ARE THE METRICS ORGANIZED?

The metrics list in the next section is divided into four parts, one for each metrics category, and includes columns for how the metric is reported (units and entry mode), the relevant outcome (hazard attenuation, biodiversity, or both), and who is intended to report on each metric (project teams, researchers, or both).

Metrics categories reflect the different roles they play in the evaluation process:

- *Project description metrics* provide details about the NBS project and its design. These are used as explanatory variables in effectiveness evaluation to inform engineering and design guidance for future projects.
- *Local context and condition metrics* provide information about the environmental conditions in which the project is located, which can influence its establishment and ability to create desired outcomes. This context is useful for project planning and siting. Many of these metrics are also used to calibrate and validate quantitative models of outcomes such as coastal hazards.
- *Ecological performance metrics* give insight into how a project is functioning ecologically, especially related to vegetation establishment and growth, which enables many target outcomes. These metrics are particularly useful to collect soon after a project is implemented and during longer-term monitoring to allow evaluation of the project's trajectory over time. Many ecological performance metrics are also inputs to quantitative models of outcomes.
- *Outcome metrics* (e.g., for hazard attenuation or biodiversity) directly measure how the project is creating target outcomes, supporting effectiveness evaluation without the need for complex modeling. These metrics can also facilitate evaluation and improvement of quantitative models.

In general, project teams would upload the project design documents or report on metrics at baseline or soon after project implementation, and researchers would return to projects later to evaluate their condition. Some metrics are flagged for measurement by both project teams and researchers to enable comparison of short-term and long-term data. The full metrics spreadsheet (available on request) contains the list of metrics, units, data entry options, measurement methods, and external sources for more detail and examples of how to measure the metric.

METRICS LIST

Project Description Metrics

Metric	Entry Mode and Units	Measured by		Relevant to	
		Projects	Researchers	Hazard Attenuation	Biodiversity
Project goals	Select from list*	✓	—	✓	✓
Prior habitat type	Select from list*	✓	—	✓	✓
Pre-project land condition/management	Text entry	✓	—	✓	✓
Pre-project hydrologic connectivity	Select from list*	✓	—	—	✓
Target habitat type	Select from list*	✓	—	✓	✓
Project size	ha	✓	—	✓	✓
Target habitat area	ha	✓	—	✓	✓
Target core area	ha	✓	—	—	✓
Project activities	Select from list*	✓	—	✓	✓
Project completion date	Date	✓	—	✓	✓
Expected project service life	Years	✓	—	✓	✓

*Note: * indicates that a drop-down list is available to select detailed metrics for specific project activities*

Ecological Performance Metrics

Metric	Entry Mode and Units	Measured by		Relevant to	
		Projects	Researchers	Hazard Attenuation	Biodiversity
Vegetated area dimensions	m	✓	✓	✓	✓
Vegetation type	Text entry (species names)	✓	✓	✓	✓
Vegetation height	cm	✓	✓	✓	✓
Vegetation stem density	stems/m^2	✓	✓	✓	✓
Vegetation stem diameter	mm	—	✓	✓	✓
Vegetated-unvegetated ratio	#, unitless	✓	✓	✓	✓
Planting survival rate	%	✓	✓	✓	—
Leaf area index	#, unitless	—	✓	✓	—
Live vegetation cover	%	✓	✓	✓	✓

Metric	Entry Mode and Units	Measured by		Relevant to	
		Projects	Researchers	Hazard Attenuation	Biodiversity
Standing biomass	g/m^2	—	✓	✓	—
Belowground biomass	g/m^2	—	✓	✓	—
Vegetation health	Text entry	—	✓	✓	✓
Vegetation species composition	Species names and % cover	✓	✓	✓	✓
Invasive plant species coverage	%	✓	✓	—	✓
Vegetation position in tidal frame	m, elevation relative to mean high tide	—	✓	✓	✓
Projected area (mangrove only)	#, unitless	—	✓	✓	—
Marsh platform slope	Degrees	—	✓	✓	—
Channel width	m	—	✓	✓	✓
Channel depth	m	—	✓	✓	✓
Channel density	m/m^2	—	✓	✓	✓
Open water coverage	%	✓	✓	✓	
Presence of foundation species	Text entry	—	✓	✓	✓
Flood-ebb suspended sediment concentration	mg/L	—	✓	✓	—
Salinity class	Select from list*	✓	✓	—	✓
Presence of invasive animals	# and names of species present	✓	✓	—	✓
Presence of mass failure blocks	Yes/no	—	✓	✓	—
Size of mass failure blocks	m^2	—	✓	✓	—
Presence of desired plant species	Species names and yes/no	✓	✓	—	✓
Presence of desired animal species	Species names and yes/no	✓	✓	—	✓
Abundance of desired species	Species names and catch per unit effort for each	—	✓	—	✓
Change in core area	ha	—	✓	—	✓

*Note: * indicates that a drop-down list is available to select detailed metrics for specific project activities.*

Context and Condition Metrics

Metric	Entry Mode and Units	Measured by		Relevant to	
		Projects	Researchers	Hazard Attenuation	Biodiversity
Tidal range	m	✓	✓	✓	✓
Wave height	m	—	✓	✓	—
Wave period	seconds	—	✓	✓	—
Wave energy spectral density		—	✓	✓	—
Water depth	m	—	✓	✓	✓
Inundation extent	m^2	—	✓	✓	✓
Elevation (bathymetry and topography)	m	✓	✓	✓	✓
Natural edge %	%	✓	✓	—	✓
Mean distance to nearest habitat neighbor	m	—	✓	—	✓

Outcome Metrics

Metric	Entry Mode and Units	Measured by		Relevant to	
		Projects	Researchers	Hazard Attenuation	Biodiversity
Incident wave height	m	—	✓	✓	—
Transmitted wave height	m	—	✓	✓	—
Shoreline position	lat/lon points	✓	✓	✓	—
Rate of shoreline position change (short-term)	m/year	—	✓	✓	✓
Rate of shoreline position change (long-term)	m/year	—	✓	✓	✓
Change in desired species diversity (Shannon index)	Index: 0–∞	—	✓	—	✓

How Can This Information Be Compiled and Shared?

We anticipate that data consistent with these metrics will be collected by members of the Nature-Based Solutions Effectiveness Data Exchange (NEDE) and their funded projects. The NEDE is currently in early stages of development. We envision that these data will be compiled in the Nature-Based Solutions Effectiveness Database (NED), which will be hosted by the NEDE.

While the metrics list looks extensive, obtaining and sharing relevant information is not as complicated as it may seem. Many of the metrics recommended for reporting by NBS project teams are characteristics of the project itself and can be sourced from project design documents. We envision that NEDE members will use online forms to streamline the data-sharing process by using basic information provided about a project to only display relevant metrics and providing standard response options for many metrics. An example form based on our coastal NBS metrics list is available here.

How Can These Metrics Be Used?

Quantitative Modeling of Hazard Attenuation Impacts

Models are often used for quantifying the influence of NBS on hazard outcomes such as wave attenuation, flooding extent and depth, and associated damages; or for assessing how the design of an NBS project influences its effectiveness for addressing hazards.

Many of the metrics in the NEDE recommended list align with data needed to run or validate quantitative hazard models. A list of frequently used models, including how the recommended metrics overlap with model data needs and potential uses for the modeled information follows. This is not a comprehensive list of hazard models, but represents the models that were most commonly seen in a literature review of the relationship between NBS and coastal hazards.

Coastal Hazard Models Used to Identify Metrics

Model	Data Needs from the Recommended Metrics List	Potential Uses for Modeled Information (Example)
Xbeach	Bathymetry, topography, vegetation height, vegetation diameter, vegetation density	Assess how NBS design influences wave attenuation (Hewageegana et al. 2022).
ADCIRC + SWAN	Bathymetry, topography; either vegetation height, vegetation diameter, and vegetation density or land cover/habitat type	Evaluate whether a NBS project is sufficient to fully attenuate waves. Assess how NBS design influences wave attenuation (Miesse et al. 2023).
DHI Mike-21	Bathymetry, topography, land cover/habitat type	Estimate reduction in flood extent and depth due to NBS. Can be combined with other models to estimate avoided flood damage due to NBS (Naryan et al. 2017).
Delft 3D	Marsh elevation, marsh platform slope, bathymetry, water depth, wave height, vegetation height, vegetation diameter, vegetation density	Assess how NBS design influences erosion (Jung et al. 2024).
SFINCS	Bathymetry, topography, land cover/habitat type	Estimate avoided flood damages due to NBS (Sebastian et al. 2021).

Modeling Biodiversity Outcomes

The project, ecological performance, and context and condition metrics presented include key metrics that determine habitat suitability for salt marsh or mangrove specialists. Value ranges for these metrics can help determine if a benefit can be expected for a species (e.g., some species have a minimum size threshold), as well as the types of benefit provided (e.g., feeding, reproduction, migratory stopover). Thus, these metrics promote understanding of how project design likely affects biodiversity response, as well as the potential for trade-offs between biodiversity and hazard attenuation outcomes.

Species distribution models are a common tool used for a variety of assessments (Araujo et al. 2019). They can be constructed using conceptual or quantitative approaches and can use the data collected to evaluate NBS projects for habitat suitability. Where existing broad-scale species or community models exist, they can help frame expected outcomes.

Research Questions

Robust evaluation of NBS effectiveness requires consistent data across many NBS projects. Several research questions related to different aspects of NBS effectiveness would benefit from the recommended metrics.

Research Questions That Recommended Metrics Can Contribute to and Data Collection Considerations to Answer Research Questions

Research Question	Data Collection Considerations to Answer Research Question
How do NBS structure and vegetation characteristics influence coastal hazard attenuation and biodiversity response?	Requires consistent data from multiple projects with different design characteristics
How quickly do new NBS projects develop coastal hazard attenuation functionality or attract key components of biodiversity?	Requires continued data collection following project construction
How do different settings and conditions influence NBS hazard attenuation and biodiversity response?	Requires consistent data from multiple projects with similar design characteristics in varying settings
How well do NBS recover after disturbance (e.g., storms) and how long does recovery take?	Requires data from before and at multiple time points after disturbance (e.g., a storm)
How does NBS recovery after disturbance influence biodiversity resilience?	Requires biodiversity data collection before and after disturbance
What are the limits of NBS ecosystem resilience—at which threshold(s) is failure likely?	Requires data from before and after multiple disturbances of varying intensities at similar projects

HOW WERE THESE METRICS DEVELOPED?

The metrics framework, recommended metrics list, and example data sharing template were developed through an iterative process beginning with a review of scientific literature, quantitative models, and existing frameworks related to monitoring and assessing the effectiveness of coastal NBS projects for hazard attenuation and biodiversity support. We used these reviews to draft an initial metrics list and framework that were refined through a series of conversations with NBS researchers, project developers, and funders. Several rounds of virtual workshops facilitated group discussions (one set of workshops focused on researchers and modelers and another on NBS practitioners and funders) to ensure the metrics were relevant to key effectiveness questions and feasible to implement. More detail on the methods used can be found here.

We incorporated existing monitoring frameworks and classifications where possible, with the understanding that these can evolve as needed with additional updates. The biodiversity metrics are aligned with the Society for Ecological Restoration 5-Star Recovery System, which identifies different aspects of ecological attributes relevant to ecosystem recovery. Habitat classifications (pre-project and target habitats) use the Global Ecosystem Typology developed by NatureServe and International Union for Conservation of Nature.

The materials presented here are considered version 1; we recognize that additional updates will be needed as the metrics and data collection template are trialed by projects and researchers.

HOW CAN YOU CONTRIBUTE?

Review metrics list. We are particularly interested in any gaps you see in what is covered (within the scope of this work as outlined above) and any recommendations to make these metrics easier to use.

Piloting data framework. We are looking for new projects willing to use our data collection framework or existing data on NBS project implementation and effectiveness to test how well it aligns with the pilot data framework. If you have data to share or would like to collaborate on piloting the data framework, please let us know.

Help build the NEDE. This network of funders, NBS practitioners, researchers, and data users is just getting started. We are looking for partners to contribute their insight or funding to developing and maintaining the NEDE. NEDE development will include not only discussions of what metrics to include and the design of a data sharing platform, but also important considerations such as how to maintain data confidentiality and what a sustainable funding model for the NEDE could look like. Additional detail can be found in the NEDE concept note. If you'd like to learn more, contact lydia.olander@duke.edu.

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