



# A Monitoring Framework for Coastal NbS: From Ecosystem Condition to Natural Capital Accounting

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# Project Goal



Develop a framework to assess whether coastal NbS and restoration have recovered ecosystem condition to a level sufficient to sustain services and benefits - with outputs ready for natural capital accounting.

## Key Challenges Addressed



Provide a framework to measure multiple outcomes and ecosystem services



Address the gap between habitat recovery and ecosystem service delivery

# Methodological Approach



## Scientifically grounded

Targeted review of existing NbS frameworks/Tools applicable to Chesapeake Bay coastal systems and management priorities.

### Key Deliverables

- ✓ Consolidated inventory of performance indicators
- ✓ Documentation of metrics and data requirements
- ✓ Gap analysis of current NbS measurement approaches



## Validated through expert engagement

Structured outreach to experts and partner organizations to document monitoring practices and resilience priorities.

### Methods & Focus

- ✓ 2 Charrette Workshops
- ✓ Identify operational constraints and opportunities
- ✓ Ensure framework reflects local context and implementation realities

# Theoretical Framework

1

## IUCN GET Typology

Habitats are classified using the IUCN Global Ecosystem Typology — seagrass meadows, shellfish reefs, saltmarshes— providing an internationally recognized scientific vocabulary.

2

## Functions → Outcomes

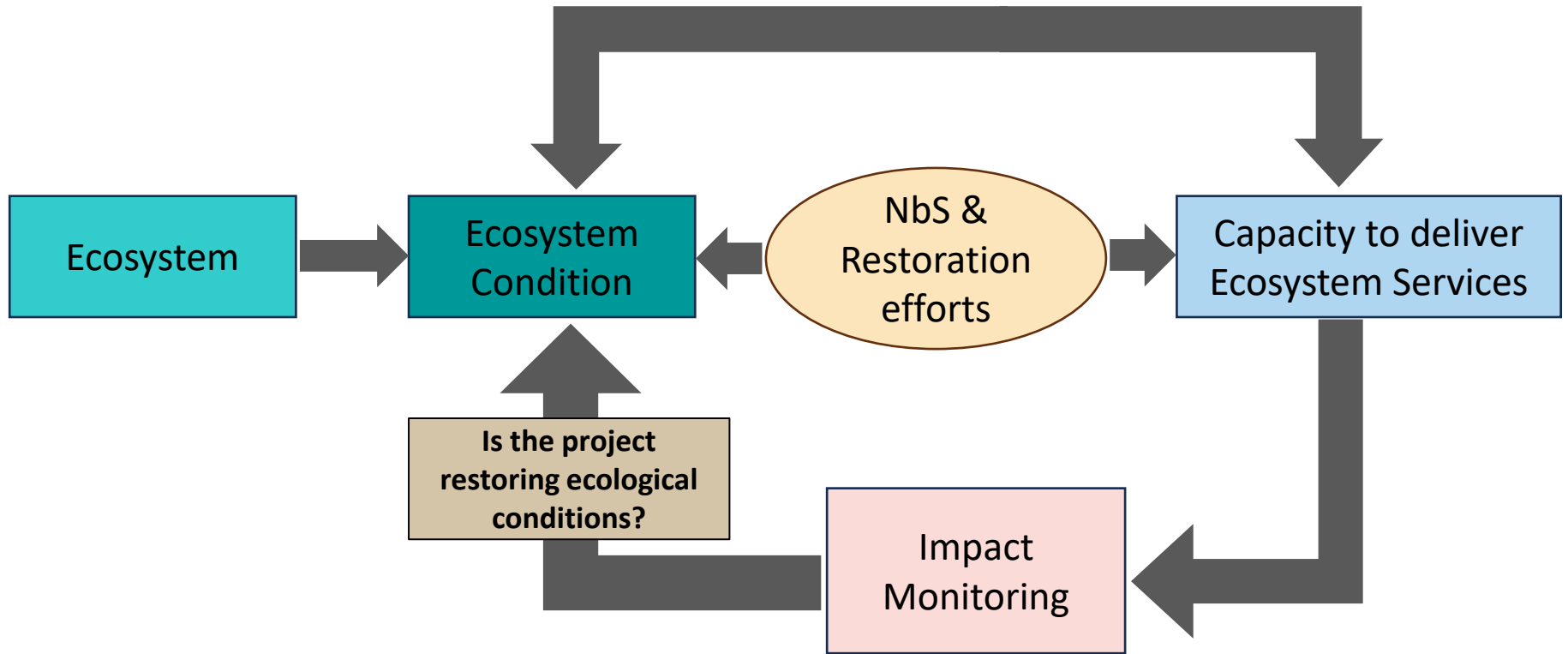
Ecological functions are the mechanistic pathways through which ecosystems deliver services. Monitoring assesses whether functions are being restored.

3

## SEEA-EA Alignment

Indicators are compatible with natural capital accounting (SEEA-EA), treating ecosystems as assets. Monitoring data can populate municipal or regional condition accounts.

# Conceptual Framework



# Selected Ecosystem Typology



Seagrass  
Meadow



Shellfish Beds  
and Reefs



Coastal Saltmarshes  
and Reedbeds

# Four Outcome Dimensions

Monitoring focuses on outcomes. Every indicator is diagnostic of one of these four dimensions.

## Coastal Hazard Risk Reduction

Wave  
attenuation,  
shoreline  
stabilization,  
flood buffering

## Climate Mitigation

Carbon  
sequestration,  
blue carbon  
stocks,  
greenhouse gas  
fluxes

## Ecosystem Integrity & Function

Habitat quality,  
biodiversity,  
ecological  
connectivity

## Socioeconomic Benefits

Recreation,  
cultural values,  
property  
protection,  
livelihood  
support

# Performance Indicators & Metrics

## Performance Indicator

*Indicators are high-level variables that represent **what we want to measure** (e.g. flood risk reduction, water quality improvement, sediment retention, recreational use).*

*They tell us what you want to assess, but not yet how to measure it*

## Metric

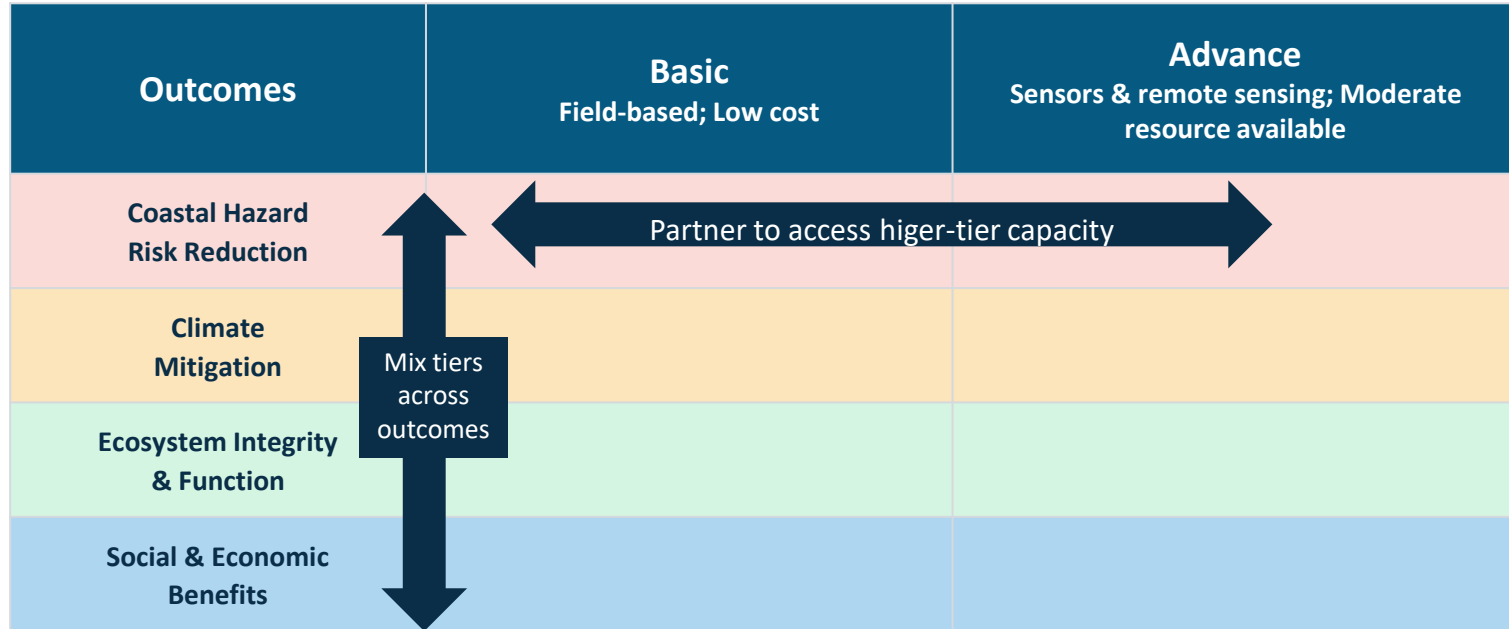
*Metrics define how we measure indicators—they are the quantifiable methods or units (e.g., % wave reduction, DO, Total nitrogen (TN) (mg L<sup>-1</sup>)).*

*Metrics make indicators measurable*

*One indicator may be quantified through multiple metrics. This distinction ensures data collection is always tied to a specific management question, not collected without purpose.*

# Flexible Monitoring Approach

*Monitoring organized by capacity, cost and data complexity*



Monitoring tiers should be match to project scale and resource available

# Ecosystem services provided by Seagrass Meadow

Ecosystem services	Coastal hazard risk reduction	Climate mitigation	Habitat quality & ecosystem integrity	Socioeconomic benefits
Water quality enhancements			●	○
Habitat provision			●	○
Fisheries support			●	○
Climate regulation		●		
Shoreline protection	●			○

**EXAMPLE**

<b>Habitat quality &amp; Ecosystem integrity Water Quality Enhancement</b>		
<b>Performance Indicators</b>	<b>Metrics</b>	<b>Source</b>
Light availability	Light attenuation coefficient ( $K_d$ , $m^{-1}$ )	Batiuk et al. 2000; Michael Kemp et al. 2004; Turner et al. 2025; Moore et al. 2014; CBP 2016; Landry & Golden, 2026; Tango et al., 2026
	% surface irradiance at depth	Batiuk et al., 2000; Kemp et al., 2004; Moore et al., 2000; Landry & Golden, 2026
Turbidity reduction	Total suspended solids (TSS, $mg\ L^{-1}$ )	Batiuk et al. 2000; Lefcheck et al. 2018; Turner et al. 2025; Landry & Golden 2026; CBP 2016; Tango et al., 2026
	Secchi depth (m)	Batiuk et al., 2000; Tango et al., 2026; CMC, 2021
Nutrient attenuation	Total nitrogen (TN), ( $mg\ L^{-1}$ )	Aoki et al. 2020; Lefcheck et al. 2018; Landry & Golden 2026; CBP 2016
	Total phosphorus (TP) ( $mg\ L^{-1}$ )	Orth et al. 2010; Lefcheck et al. 2018; Landry & Golden 2026; CBP 2016
Phytoplankton suppression	Chlorophyll a $\mu g\ L^{-1}$	Orth et al. 2010; Gurbisz & Kemp 2014; Lefcheck et al. 2018; CBP 2016; CMC 2021; Tango et al., 2026
Dissolved Oxygen support	Dissolved oxygen ( $mg\ L^{-1}$ )	Gurbisz & Kemp 2014; Hendriks et al. 2014; Landry & Golden 2026; CBP 2016; CMC 2021; Tango et al., 2026

# Example of Indicator Infosheet

## WATER QUALITY ENHANCEMENT

### Turbidity Reduction

Outcome dimension: Habitat Quality & Ecosystem Integrity

#### INTENT

Turbidity is the cloudiness or haziness of water caused by suspended particles. This water quality parameter directly limits light penetration essential for submerged aquatic vegetation, filter-feeding organisms, and trophic productivity. This indicator tracks whether coastal nature-based solutions are improving water clarity over time, a core signal of restored ecosystem function and reduced sediment loading. Reductions in turbidity reflect the combined effect of vegetative stabilization, particle trapping, and biological filtration by NbS habitats such as seagrass meadows, saltmarshes, and oyster reefs.

#### METRICS

**BASIC (Optical Method):** SD Secchi depth *m*

**ADVANCED (Gravimetric or SSC):** TSS Total suspended solids  $mg\ L^{-1}$

#### MEASUREMENT METHODS

1. Gravimetric Method (Lab Standard — EPA 160.2 / SM 2540D)

2. Optical Methods (Field/Continuous Monitoring)

3. Suspended Sediment Concentration — SSC (USGS)

4. Remote sensing

#### PERFORMANCE SCORING:

Multi-year positive trend established; Positive trend observed; Baseline measured; Negative trend observed; Unchanged trend

# Monitoring Outputs as Natural Capital Accounting Inputs



Indicators and metrics tracking ecosystem health, structural integrity, and functioning over time



Time-series data used to assess changes in ecosystem asset integrity



Metrics rescaled against ecological reference levels to measure distance from a pristine or intact state



Supports understanding of nature dependency and long-term sustainability for businesses and governments



## Why This Matters?

- Ecosystem condition predicts future service flow (degraded ecosystems supply fewer services)
- Tracks societal risks by revealing hidden dependencies in sectors like agriculture, fisheries, and tourism before economic losses occur
- Standardizes environmental economics through condition indicators aligned with frameworks like SEEA
- Guides policy and finance by supporting targeted conservation investments based on baseline conditions and future scenarios

# From Monitoring Data to Cost-Benefit Evidence

Supporting Green vs. Grey Infrastructure Comparison

Quantified ecosystem services become measurable benefit streams for CBA

Condition accounts provide the baseline and trajectory to compare NbS against engineered alternatives over time

Co-benefit monetization gives decision-makers evidence to justify green infrastructure investment

# Future Work

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01

## Expand Coverage

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Extend framework to additional coastal ecosystem typologies

Ground indicators in site-specific restoration targets

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## Functional Condition Benchmarks

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Derive reference points from sites, literature & expert judgment

Link recovery thresholds to ecosystem service delivery

03

## Condition as a Continuum

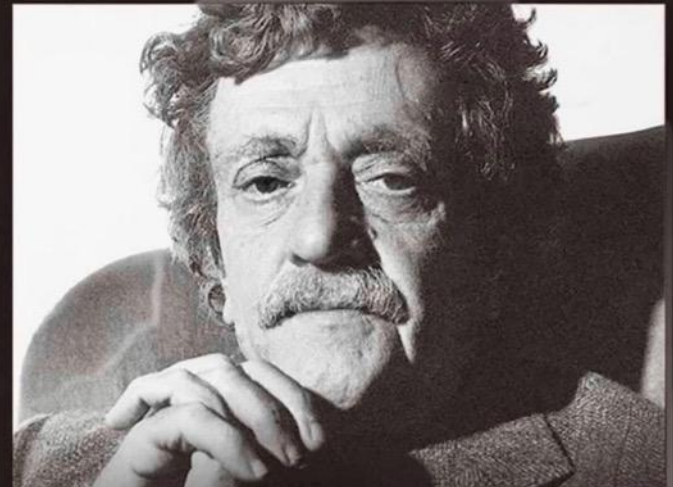
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Assess success via trends & trajectories

Enable adaptive management through benchmark comparison

Feed condition trajectory data into natural capital accounting

Thank You  
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We'll go down in history  
as the first society  
that wouldn't save itself  
because it wasn't  
cost-effective.

**Kurt Vonnegut,**

American writer and novelist

(1922 — 2007)