Efforts to Develop Standardized Socio-Economic and Ecological Performance Metrics for Natural Infrastructure

Dr. Susan Taylor, Abt Assoc

Kim Penn, NOAA OCM

Dr. Rick Bennett, FWS

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Natural Infrastructure Metrics



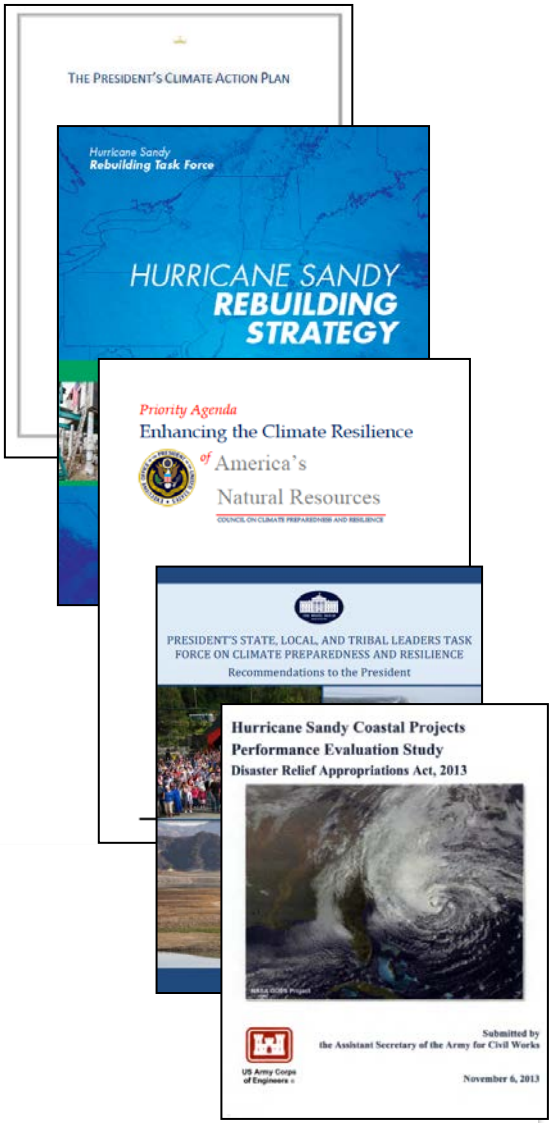

- **Metric defined: *a measure or suite of measures (index) that can be used to detect change***
  - **… No clear measures of change in resilience**
- **We know natural infrastructure provides services to ecosystems and communities**
  - **… But we do not have a handle on what these are**
- **Decision makers and engineers need to know what will work**

Overview of Presentation

1. **Highlight drivers**
2. **Challenges**
3. **Overview of metric workgroups**
4. **Describe socio-economic metrics**
5. **Introduce interagency Natural Infrastructure Metrics group (NIMs)**

1. Drivers

- EO 13653 *Preparing the US for the Impacts of Climate Change* (est. Interagency Council on Climate Change Preparedness and Resilience)
- *Priority Agenda for Enhancing the Climate Resilience of America's Natural Resources* requires agencies to "design an Ecosystem Resilience Index"
- **Federal activities:**
  - Coastal Green Infrastructure and Ecosystem Services (CGEIS) Task Force (research agenda)
  - Community Resilience Index (FEMA, NOAA, NIST)
  - Climate Resilience Toolkit (OSTP, CEQ)
  - Evaluate USACE projects impacted by Sandy



Other Activities

- TNC: Risk Reduction and Resilience Metrics Workbook, Restoration Explorer
- EPA: Final Ecosystem Goods and Services, National Ecosystem Services Classification System
- TPL: Urban metrics (not yet conservation)
- Academia: VIMS, Stevens Institute, Partnership for Delaware Estuary
- USACE North Atlantic Coast Comprehensive Study (NACCS)
- DOI Metrics Expert Group (DMEG)
- Natural Infrastructure Metrics workgroup (NIMs)

2. Natural Infrastructure Challenges

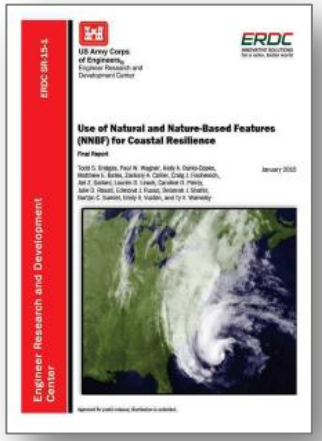
- All efforts begin with discussion and re-defining of indicator and metric
- Agencies and organizations vary with definitions of resilience and mission focus
- Monitoring – no funding, no consistency, etc…
- Scaling
- Overarching needs: Performance and cost-effectiveness

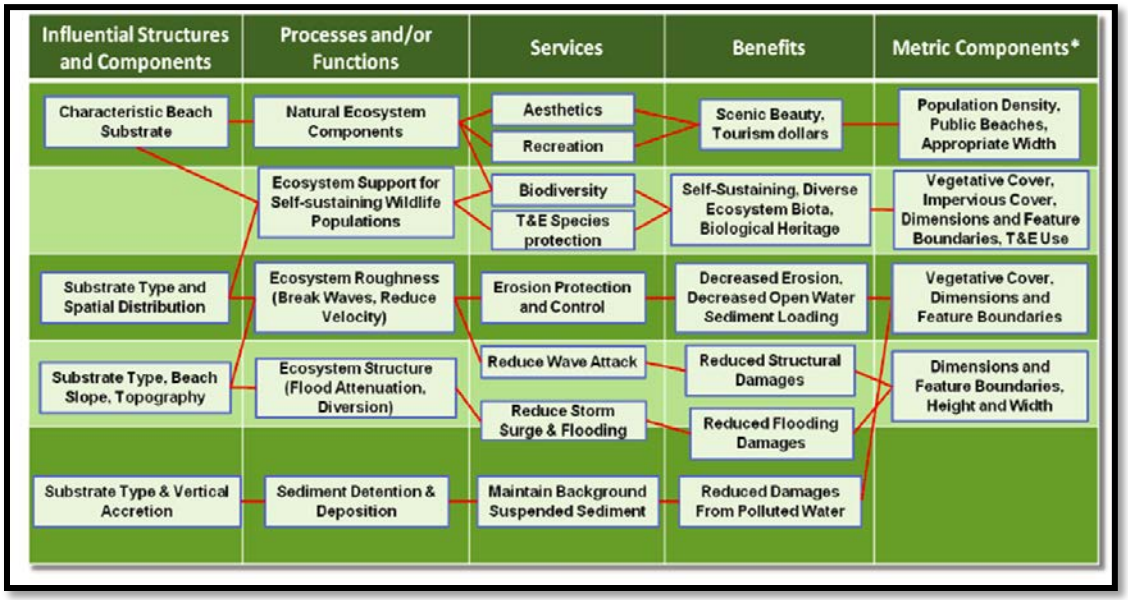
"If resilience is built through a project, and no perfect resilience metric is around to measure it, does it have an impact?"

Anonymous, National Adaptation Forum, St. Louis, MO 2015

3. Overview of Metric Workgroups

USACE NACCS





- Objective is resilience (re-establish or enhance)
- 30 features related to recovery efforts (NNBF, Feature Complexes, Structural)
- 21 ecosystem-based goods and services, 72 “quantitative” performance metrics

http://www.nad.usace.army.mil/CompStudy

3. Overview of Metric Workgroups

DOI Sandy Program

- Opportunity: DOI funded over 150 resilience projects (~$340 million)
- Objective to identify measurements to assess change in coastal resilience
- DMEG Goals:
  - Recommend metrics for DOI resilience assessment
  - Determine data and information gaps
  - Recommend core metrics for the DOI resilience assessment

Process:

Organized metrics around 6 coastal features

Identify core metrics (Abiotic, Biotic, Structural)

Peer review

Benefits: project comparisons and regional resilience assessments

Table 1. Recommended ecological core performance metrics by coastal feature for Department of the Interior Resilience projects funded through the Disaster Relief Recovery Act of 2013.

Natural and Artificial Coastal Features	Primary Objectives and Ecosystem Services	Recommended Core Performance Metrics
Beach System: Beach, Barrier Island, and Dunes (for back bay areas, see Estuaries and Ponds)	Beaches and Dunes: 1) Restore or improve beach habitat to enhance resilience of fish, wildlife, and plants, and their habitats (e.g., spawning, migration stopovers, critical habitats) 2) Restore/improve dune habitat to enhance resilience of coastal infrastructure by reducing flooding extent and attenuating wave energy 3) Improve/sustain beach/barrier island ecological system and community resilience to storm surge events 4) Enhance understanding of natural system dynamics including immediate storm responses, natural recovery from disturbance events, and natural adaptation capacities and tendencies. 5) Improve recreation/aesthetics Breaches: 1) Manage breach occurrences to maximize ecosystem function and reduce risks to built infrastructure, human health, and human safety.	Beaches and Dunes: Biotic • Vegetation cover of dunes pre and post event • Fish and wildlife population/ recruitment/ overwintering/stopover weight/health relative to other mitigating factors (e.g. other threats throughout range: site and species specific) Abiotic • Post-storm volume of sand in the active shoreface • Recovery rates of beach and dunes Structural/Engineering • Beach width, elevation, volume, shoreline position (post-event) • Dune characterization (height, width, length, texture, substrate) Breaches: Biotic • Fish and wildlife population/ recruitment/ overwintering/ stopover weight/health changes relative to other mitigating factors (e.g. other threats throughout its range: site and species specific) Abiotic • Volumes of material in flood and ebb shoals • Water flow and current dynamics • Water quality: temperature, salinity, pH, dissolved oxygen, turbidity, nutrients, contaminants • Water level changes, especially in back bays Structural/Engineering • monitoring of breach morphologic changes

Core Performance Metrics:

A set of performance metrics that are applied to multiple projects and at the full range of temporal and spatial scales to represent a change in resilience in one or more coastal features.

4. DOI Socio-Economic Metrics

Initial Tasks:

Information Gather (classification, lit review, interview)

4 Resilience Output Categories (and 16 resilience goals)

Link Project Activities to Outcomes and then Outcomes to Resilience Goals (*e.g. causal chains*)

- Support DOI and NFWF with development of measures of community well-being and resilience
- Communicate value of projects with social relevance
- Objectives: Develop socio-economic metrics and assign to each project

Classification

Information Gather (classification, lit review, interview)

4 Resilience Output Categories (and 16 resilience goals)

Link Project Activities to Outcomes and then Outcomes to Resilience Goals (*e.g. causal chains*)

Project Activity Category	# Projects Assigned with one activity	# Projects in multi-activity projects
Community Resilience Planning	2	19
Contaminant Assessment or Remediation	3	4
Critical Infrastructure Assessment or Protection	N/A	3
Data, Mapping, and Modeling	40	60
Ecological Resilience Planning	1	13
Green Infrastructure Planning and Implementation (living shorelines, etc.)	6	33
Grey Infrastructure (dams, culverts, berms)	12	26
Habitat Restoration	11	49
Impact or Vulnerability Assessments	11	24
Public Access	N/A	5
Sand Resource Identification or Assessment	13	13

Resilience Categories

Organize into categories to ensure metrics link to socio-economic benefit and resilience definition

Resilience Categories

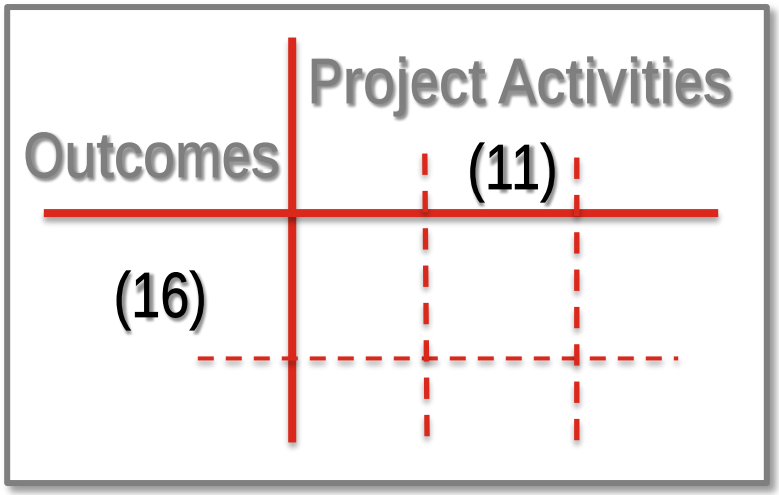
1. **Human Health and Safety**
2. **Physical Infrastructures**
3. **Economic Resilience**
4. **Community Competence and Empowerment**

Information Gather (classification, lit review, interview)

4 Resilience Output Categories (and 16 resilience goals)

Link Project Activities to Outcomes and then Outcomes to Resilience Goals (*e.g. causal chains*)

Map Activities to Resilience Goals



Finally, 16 goals identified, unique to each of the four resilience categories

Information Gather (classification, lit review, interview)

4 Resilience Output Categories (and 16 resilience goals)

Link Project Activities to Outcomes and then Outcomes to Resilience Goals (*e.g. causal chains*)

Project Actions → **Project Outcomes** → **Resilience Goals** — Metric

Project Actions		Project Outcomes		Resilience Goals		
Acres of coastal wetland restored	→	Increase in average elevation within floodplain	→	Reduction in storm surge height	→	Reduced exposure to storm surge (e.g. number of people affected) → Decrease in number of injuries or casualties

Ecological Indicators

Biophysical indicators directly relevant to socio-economic resilience

Example: Human Health and Safety

Ecological Outcomes

- Changes in floodplain area
- Changes in the maximum height of water from a particular flood

- Improved water quality
- Reduced soil contamination
- Increase in % native vegetation
- Improved water management and fire control

Socio-economic Metrics

Reduction in # of households exposed to flood hazard

Reduction in # people exposed to contaminated water, soil, mosquito-borne disease, and wildfire

Metrics: Property and Infrastructure Protection

	Metrics for Property and Infrastructure Protection	Resilience Goals		
		Reduction in number of residential, commercial, cultural, and heritage properties at risk to potentially damaging inundation	Reduction in miles of roads, highways, and rail lines at risk to potentially damaging inundation	Reduction in number of critical service facilities at risk to potentially damaging inundation
		Metrics[a]		
Biophysical and Ecological Outcomes	Reduced extent of damaging inundation from major storm and flood events[b]	1. Reduction in number of properties exposed to flood event with the project as compared to without 2. Reduction in percentage of total residential and commercial property value expected to be damaged in floods with the project as compared to without 3. Property value of residential and commercial properties exposed to a flood event with and without project 4. Tax base attributed to residential and commercial properties exposed to a flood event with and without project 5. Reduction in expected damages to properties from floods with the project as compared to without	1. Reduction in miles of transportation infrastructure exposed to a flood event with the project as compared to without 2. Reduction in number of users potentially affected due to exposed transportation infrastructure 3. Avoided repair/replacement cost to transportation infrastructure exposed to a flood event 4. Avoided days of closure of transportation infrastructure	1. Reduction in number of critical service and utility facilities exposed to a flood event with the project as compared to without 2. Reduction in number of users or customers potentially affected due to disruption of critical services or utilities 3. Avoided days of closure or disruption of critical services or utilities
	Reduced hazard of nuisance flooding[c]			

. Metrics are numbered in order of increasing level of detail and potential difficulty in measuring
. Major storm and flood events are defined as FEMA's 0.2%, 1%, 2%, or 5% flood events.
. Nuisance flooding is defined as flood events that occur at least every year or more.

Metric Methodological Components

Translate core ecologic metrics to biophysical changes relevant to socio-economic resilience

Estimate affected populations or properties and infrastructure components

Construct socio-economic resilience metrics

***Example*: Reduced exposure to flood hazard and damaging inundation**

1. Use project data or simplified approaches to estimate affected area (& with and without project)
2. Spatial overlay inundation with population, infrastructure (& vulnerability data)
3. Metrics calculation options range from simple counts and narratives to complex environmental modeling

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***Example*: Reduced exposure to flood hazard and damaging inundation**

1. Use project data or simplified approaches to estimate affected area (& with and without project)
2. Spatial overlay inundation wit
   erability
   tions ra
   plex er

Restored wetlands reduce floodplain by X acres and thus protect 10 miles of critical access road used by 4,000 people per day

Restored wetlands result in avoided road closure of 5 days every 5 years. Avoided road closure reduces commuting time by 20,000 hrs during each week of closure

Methodologies:

- Provide recommendations on scaling and important considerations for each resilience category
- Methods and data provided for estimating biophysical changes, affected area, changes in the resilience of each category

Exhibit 12. Methodologies for Property and Infrastructure Protection and Enhancement, mapped to resilience goals, project outcomes, and core metrics.

Socio-Economic Resilience Goals	Project Outcomes	Performance Metrics	Possible Methodologies[a]
Reduction in number of residential, commercial, cultural, and heritage properties at risk to potentially damaging inundation	Reduced extent of damaging inundation from major storm and flood events[b] and reduced hazard of nuisance flooding[c]	Reduction in number of properties exposed, reduction in percentage of total residential and commercial property value exposed, increase in property value, increase in tax base attributed to properties, reduction in expected damages	• Low: Use changes in a community's ranking or participation in the NFIP's CRS program as a proxy to indicate improved protection of infrastructure. • Medium: Demonstrate the link between the project actions and increased protection to infrastructure functionality by using one of the methods described for estimating biophysical change. • High: Model the effects of the project using a spatial overlay of the extent and depth of inundation with property and infrastructure components with and without the project using Hazus-MH.
Reduction in miles of roads, highways, and rail lines at risk to potentially damaging inundation		Reduction in number of miles exposed, reduction in number of users affected, avoided damage cost, avoided days of closure or disruption	
Reduction of critical service facilities at risk to potentially damaging inundation		Reduction in number of critical service and utility facilities exposed, reduced in number of users or customers affected, avoided loss of critical service and utility facilities, avoided days of closure or disruption	
Property enhancement from improved amenities	Improved water and soil quality, reduced soil contamination, restored beaches, dunes, improved fish and shellfish habitat; increased fish and shellfish abundance and	Number of residential, commercial, cultural, and heritage properties benefiting, property value of residential and commercial properties, tax base attributed to residential and commercial properties benefiting, increase in property value of residential	• Low: Spatial overlay with the estimated of affected area and properties • Medium: Demonstrate the link between the project actions and increased protection to infrastructure functionality by using one of the methods described for estimating biophysical change. • High: Actual changes in property values resulting from environmental quality improvements can be estimated based on an

Metric Assignment

	A	F	G	H	I	J
1	**Resilience Categories→**	operty and Infrastructure Protection and Enhancement		Economic Resilience		
2	**Resilience Goals→**	**P3) Reduction of critical service facilities at risk to potentially damaging inundation**	**P4) Enhancement of property and infrastructure components from improved amenities**	**E1) Reduction in quantity of tourism and recreational infrastructure at risk to flood hazard**	**E2) Reduction in quantity of commercial fishing, shellfishing, and aquaculture infrastructure at risk to flood hazard**	**E3) Reduction in sha agriculture land at r flood hazard**
4	**Project Outcomes↓**					
16	**12) Reduced extent of damaging inundation from major storm and flood events**	1. Reduction in number of critical service and utility facilities exposed to a flood event with the project as compared to		1. Reduction in number of buildings (e.g., hotels and summer rentals), recreational facilities, and amenities exposed to	1. Reduction in number of boat launches, warehouses, fishing vessels, and aquaculture leased bottom exposed to	1. Reduction in num acres exposed to flo hazard or increased salinity 2. Avoided economi
17	**13) Reduced haza flooding**					

If a project includes:	HHS metrics categories	PI metric categories
Community Resilience Planning		
Contaminant Assessment or Remediation	H2.15; H2.10	P4.14; P4.10
Critical Infrastructure Assessment or Protection		P2.12; P3.12; P2.13; P3.13
Data, Mapping, and Modeling		
Ecological Resilience Planning		
Green Infrastructure Planning and Implementation (livir	H1.12; H2.13; H2.10; H2.8; H2.3	P2.12; P3.12; P2.13; P3.13; P4.10; P4.11; P4.8; P4.5
Grey Infrastructure (dams, culverts, berms)	H1.12; H2.13; H2.3	P2.12; P3.12; P2.13; P3.13; P4.11
Habitat Restoration	H1.12; H2.13; H2.10; H2.9; H2.8; H2.3	P2.12; P3.12; P2.13; P3.13; P4.10; P4.11; P4.8; P4.5
Impact or Vulnerability Assessments		
Public Access		P4.5
Sand Resource Identification or Assessment		

5. Natural Infrastructure Metrics workgroup (NIMs)

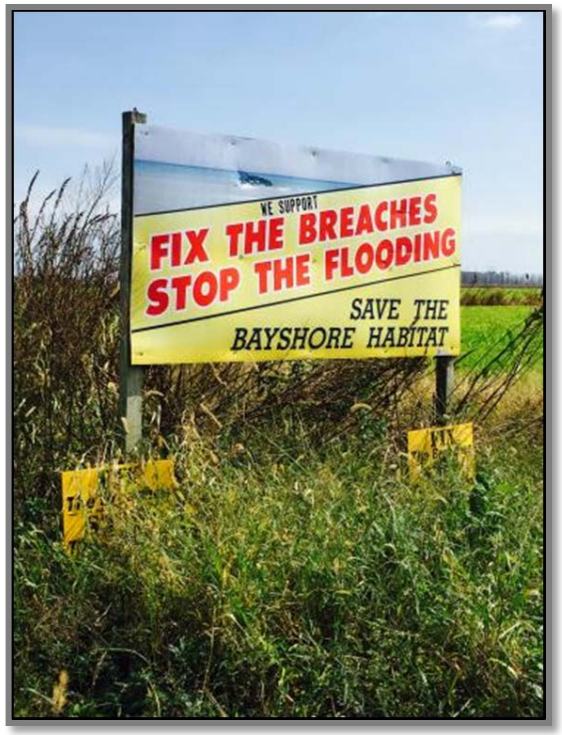
Goal: Develop core metrics that cut across agency missions, supporting efficiencies and knowledge base that demonstrate ability of natural infrastructure as:

- ✓ Effective
- ✓ Resilience
- ✓ Cost Effective

Audience: agencies, practitioners, academics, stakeholders

NIMs Objectives

- Identify and develop metrics to measure the success of existing and planned ecosystem and community resilience projects
- Demonstrate proof of concept: partners are expected to measure something that they normally do not
- Focus on coastal resilience
- Highlight gaps and steps to fill these gaps in the future



NIMs Approach

Evolution of Thinking:

1. Develop a set of metrics to measure the success of NI projects (by Agency mission). Metrics would ideally be tested in cost-benefit analyses.
2. Identify the ecosystem services you (your organization) wants from NI that addresses your agency mission. Then provide the metric.
3. Organize metrics by ecosystem services and by landscape feature.

- Convene multi-agency/organization team
- Compile a list of intermediate and final services per organization
- Compile list of metrics per organization
- Identify and fill knowledge gaps
- Select a common core set of metrics
- Implement with pilots

NIMs Services

Ecological	Provide Habitat; Maintain Biodiversity; Protect TES; Buffer Ocean Acidification
Sociological	Provide Recreation; Provide & Support Navigation; Produce-Provide Food, Feed, etc.; Provide & Improve Aesthetics; Promote Environmental Justice; Protect Property Value; Protect Cultural Heritage; Provide & Support Education; Provide-Support Scientific Research
Hydrological	Reduce Storm Surge & Flooding; Provide Flood Storage; Attenuate Waves; Provide and Store Groundwater; Reduce Overtopping; Reduce Current - Wave Velocity; Restore Functional Hydrology
Geological	Reduce & Control Erosion; Protect & Enhance Healthy Soils
Biogeochemical	Improve Water Quality; Sequester & Convert Nutrients; Reduce Hazardous-Toxic Materials
Climatological	Regulate Microclimate; Sequester Carbon
Other	Reduce Wildfire Potential; Protect Against Wind Shear; Attenuate Drought

31 total [draft] services (intermediate and final)
12 Features

NIMs Table

Good or Service:	ECOLOGICAL	SOCIOLOGICAL			HYDROLOGICAL	
	Maintain Biodiversity	Provide Recreation	Protect Property Value	Protect Cultural Heritage	Reduce Storm Surge & Flooding	Provide Flood Storage
Features	Metrics					
Nearshore Shallow and Nearshore Deep (includes submerged aquatic vegetation and/or aquatic vegetation bed both fresh and saline)	density of each species of species group (individuals/unit area of measurement)	number of visitors to the site	number of homes within walking distance that would benefit from open space, which could be assessed using GIS software	social;/cultural value that individuals place on the resource, which can be valued using a stated preference method such as contingent valuation or a choice experiment	SEAGRASS BEDS: Area of Seagrass	
	CONNECTIVITY: 1)is connectivty needed and type of connectivity required; 2) importance of the connectivity (area/zone/system) for habitat persistence; 3) importance of the connectivity (area/zone/system) for ecosystem service provision; 4) protection of connectivity, including if it can be protected	value that visitors place on the recreational experience	change in property values due to an increase in natural space, analyzed through a hedonic valuation study	cultural indicators can be developed based upon feedback from residents through focus groups, interviews or surveys. These indicators may fall into a variety of categories, such as quality of life, shoreline activities, sense of place, or sommunity well-being and will vary depending upon habitat type, project, and relevance to the community	SEAGRASS BEDS: species composition	
			change in property values due to a perceived decrease in flood risk, analyzed through a hedonic valuation study		SEAGRASS BEDS: mean shoot density	
			change in property values due to an improvement in water clarity, analyzed through a hedonic valuation study		SEAGRASS BEDS: mean shoot height	

NIMs Next Steps and Time Line

In Progress:

- ✓ Comprehensive compilation (& cleaning) of all responses by service and feature (*removing affiliations)*
- ✓ Create sample causal chain for report
- ✓ Organize and determine prioritization/ process to determine core metrics

March 2016:

- Draft metrics out for peer review
- Release metrics and report

Next Steps (2016):

- Test metrics on pilot sites
- Integrate with other efforts (e.g. Ecosystem Resilience Index)
- Revise based on additional agency and expertise feedback to report

http://sagecoast.org/

Closing Remarks

- Variety of metric efforts all moving past academic studies to implementation
- Multiple metric efforts and missions: landscape/GIS (NACCS), field (DOI), regional/place based (academia/state agency)
- **Path Forward:**
  - NIMs workgroup attempting to bring diverse parties to the table and collect metrics for services across diverse missions.
  - Collection of metrics to inform and continuously advance best practices over time
  - Prioritize metrics and present range of options to ensure measures feasible
- **Success will involve:**
  - Understanding the benefits of green and adding green to grey
  - Laborious baseline, bench-marking, and tracking (& collaboration)
  - Everyone doing their part

Dr. Susan Taylor, Abt Associates
Susan_Taylor@abtassoc.com

Kim Penn, NOAA OCM
kim.penn@noaa.gov

Dr. Rick Bennett, FWS NE Region
rick_bennett@fws.gov