The groundwork for common monitoring approaches in the SNEP region

Operationalizing the Integrated Ecosystem Services Framework to prioritize indicators and metrics of ecosystem function and health

Final report on

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1 Introduction

1.1 Background

Ecological assessments must be supported by meaningful metrics of ecosystem condition and improvement. If chosen and developed wisely, the same metrics can also be used to show how public funding affects the protection and restoration of the environment and all of the benefits nature provides to communities. Many protection and restoration actions succeed only after years or decades of continued investment, with interim progress invisible or obscured by persistent and unremitting impacts to the ecosystem.

The Southeast New England Program (SNEP) has spent the last few years working with experts in the region to discuss and identify a reasonable approach for measuring, compiling, and communicating changes in water quality, habitat condition, and ecosystem services on a regional scale. SNEP has identified many challenges to implementing a common approach, including differences in the underlying purpose of monitoring (i.e., different environmental mandates), differences in the methods and forms of monitoring conducted by numerous entities, and the varied scales at which monitoring is conducted (often related to funding and staff capacity).

To address these challenges, SNEP initiated a project under contract to develop an Integrated Ecosystem Service Framework (IESF): a conceptual structure for broadly describing the relationships between and among ecosystem conditions (indicators and metrics) and the resulting benefits (ecosystem goods and services) to people (beneficiaries). Inherent in the IESF structure is the concept that altered conditions lead to altered benefits delivered to communities.

1.2 Purpose of this report

This report describes the contract work to establish the IESF, which can help inform decision-making on:

- Appropriate indicators and metrics for assessing environmental condition and program impact.
- Developing commonality within and between monitoring approaches.
- Framing management/restoration/protection outcomes and other human activities using ecosystem services and valuation approaches.
- The format and content of periodic “State of the SNEP region” reports.

Simultaneous work on several separate tasks, over a 12-month contract, contribute to the IESF’s development. This report synthesizes the results of these tasks and culminates with an example-driven demonstration of how SNEP can use—or “operationalize”—the IESF to prioritize indicators and metrics of ecosystem function and health in the region.

1.3 Overview of report sections

Section 2 of this report describes management questions that could drive SNEP's monitoring focus. Management questions should reflect the basic human needs or ecosystem services that the SNEP community values and represent issues that SNEP should focus on over the next five to 10 years. These issues were informed by workshops with the SNEP Subcommittees in 2019 under the previous contract; meetings held in 2020 under this contract (**Task 3**); a spatial data compilation showing a snapshot of ecological conditions, services, and beneficiaries in the SNEP region (**Task 2C**—see appendix); and the results of a social media analysis to determine what nature-based topics people in the SNEP region most often tweet about (**Task 4D**—see appendix).

Section 3 summarizes the current monitoring activities and data gaps in the SNEP region at the program level and project level. These results come from two major literature reviews and inventories: the **Task 2A** literature review of geographic/regional monitoring programs across the United States and programs conducting monitoring within the SNEP region (appendix); and the **Task 4A** review and characterization of monitoring conducted via SNEP-funded projects (appendix). This section also includes a summary of data gaps (**Task 4B**) and recommended data collection to address gaps (**Task 4C**) based on comparisons between SNEP monitoring and other geographic programs.

Section 4 describes the development of the conceptual IESF. The IESF was developed and populated (**Task 2B**) with extensive input from SNEP Subcommittees (appendix).

Section 5 of this report describes a potential workflow for operationalizing the IESF toward developing monitoring strategies that address key management questions. This section ties together the findings in the previous three report sections, as well as the results of a pilot valuation study conducted in **Task 5** (appendix).

Finally, Section 6 makes recommendations about developing a SNEP monitoring framework based on the lessons learned from all tasks.

1.4 Report nomenclature

Because the work required the consideration and organization of a vast amount of data, the project sought to use consistent nomenclature.

For ecosystem services, terminology from The Economics of Ecosystems & Biodiversity, or TEEB (McVittie and Hussain, 2013) was employed. The TEEB global initiative builds on the ideas developed in the Millennial Ecosystem Assessment (2005) and aims to promote understanding of the economic value of ecosystem services. TEEB describes four broad categories of ecosystem services, to which we refer throughout this report: cultural services, habitat or supporting services, provisioning services, and regulating services.

When referring to types of beneficiaries, the report employs terminology derived from the U.S. EPA Final Ecosystem Goods and Services Classification System (FEGS-CS) (Landers and Nahlik, 2013).

The project and this final report did not distinguish between the terms “indicators” and “metrics.” These terms are usually used together in a single phrase throughout the report, e.g., “indicators and metrics.” SNEP Subcommittee members were not asked to define these terms or provide criteria to distinguish them. In describing existing monitoring efforts, we adopted the conventions used by the individual programs that communicated results of the monitoring. As SNEP begins to choose or develop indicators and metrics, there is likely a need to be more explicit about what these words mean and more deliberate with how they are used.

2 Potential management questions

2.1 Background

SNEP has been working with regional experts through the SNEP Monitoring Subcommittee and Ecosystem Services Subcommittee for the past few years to develop and recommend a core set of common indicators that would constitute a regional monitoring framework to assess change in conditions, and to answer key management questions. The work to identify of a core set of common indicators is addressed in Section 3 of this report and is supported by the program- and project-level monitoring inventories. The identification of potential management questions and a potential set of core indicators has been happening in parallel. In practice, each activity can inform the other in an iterative fashion, as shown in Figure 1.

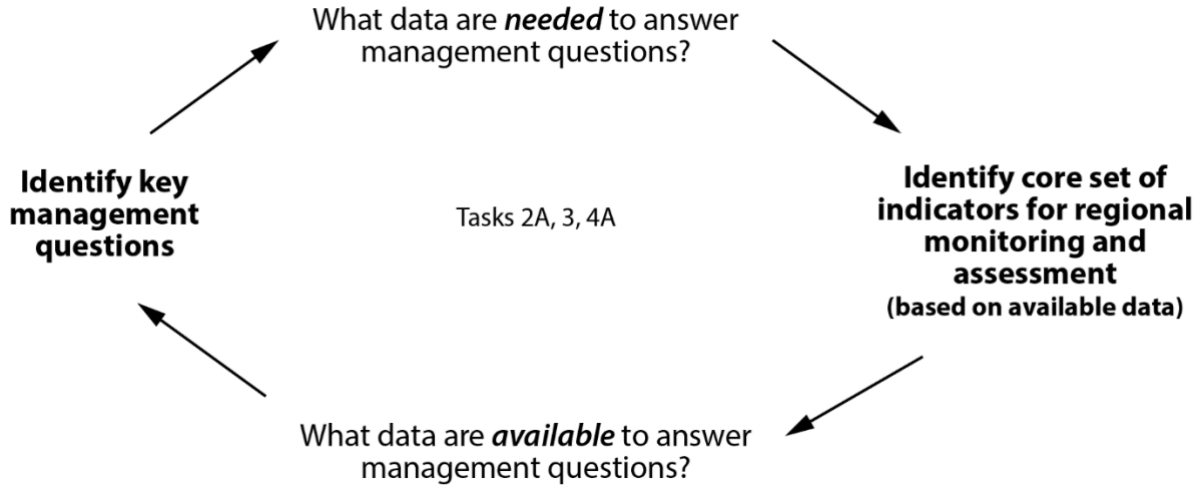


Figure 1. Workflow diagram showing the iterative steps to identifying key management questions and a core set of indicators for regional monitoring and assessment.

In 2019, the Ecosystem Services Subcommittee requested additional information on what monitoring data were available in the region before recommending focal monitoring questions. Similarly, the Monitoring Subcommittee found it difficult to prioritize monitoring data and indicators until the important management questions were defined. However, both Subcommittees agreed that key management questions should reflect the basic human needs or ecosystem services that the SNEP community values. This is because public support for monitoring (and management) will be greatest if SNEP can demonstrate how monitoring data are used to answer questions about management or regulatory actions that affect our everyday lives (e.g., Why was my neighborhood required to connect to a sewer?). That said, there was a recognition that regulatory management questions and those that relate to other types of management interventions likely require different monitoring approaches, and since the results are each targeted to different audiences, reporting would also be different.

In memos and workshop summaries from 2019, both Subcommittees articulated several potential management questions that they considered to be important. We repeat these potential questions below, organized by the relevant ecosystem service(s) they address and the potential target audience for each.

2.2 List of potential management questions by ecosystem service

The existing draft list of potential management questions was grouped into sets of issues and associated ecosystem services based on the SNEP Subcommittees' input throughout 2019 and 2020, the initial results of the social media analysis of nature-based tweets in the SNEP region in Task 4D (appendix), and EPA's own prioritization of spatial data products in Task 2C (appendix).

The ecosystem services listed with each question are meant to capture the final ecosystem good or service (e.g., commercial fishing generates food [a provisioning service]) as well as the intermediate services (e.g., commercial fishing relies on nursery habitat [habitat or supporting services] and good water quality [regulating services] to generate food [a provisioning service]). The questions fall into five groups of issues and associated ecosystem services.

1. Cultural and regulating services from beaches and other water-related recreation (Table 1)
2. Habitat or supporting, provisioning, and regulating services from natural shellfish beds and aquaculture (Table 2)
3. Habitat or supporting and regulating services from wetlands and coastal vegetation (Table 3)
4. Cultural and regulating services from water quality and clarity (freshwater and marine) (Table 4)
5. Cultural, provisioning, and regulating services from commercial and recreational fishing (Table 5)

We also created a sixth group of questions that could help reflect the value of SNEP-funded projects and programs in the region, including the explicit impacts of restoration or protection actions (Table 6).

Table 1. Potential management questions—cultural and regulating services from beaches and other water-related recreation.

Potential management question	Associated ecosystem services	Target audience(s)
What is the cost of a beach closure locally?	Cultural; Regulating	General public; Municipalities
Is it safe to swim at the beach?[1]	Cultural; Regulating	General public
Are beach closures decreasing?	Cultural; Regulating	General public; Municipalities; State/fed govt
What are the similarities and differences in how excess nutrients affect opportunities for recreation in each watershed?	Cultural; Regulating	State/fed govt

Table 2. Potential management questions—provisioning, habitat or supporting, and regulating services from natural shellfish beds and aquaculture.

Potential management question	Associated ecosystem services	Target audience(s)
How do shellfish alter nitrogen provision in the system?	Habitat or supporting; Regulating	Municipalities; State/fed govt
How much aquaculture is permitted?	Habitat or supporting; Provisioning; Regulating	General public; Municipalities; State/fed govt
How do you give credit for N-removal if you aren't removing shellfish?	Habitat or supporting; Regulating	State/fed govt
What is the impact of coastal acidification on shellfish?	Habitat or supporting; Provisioning; Regulating	General public; Municipalities; State/fed govt

Table 3. Potential management questions—habitat or supporting and regulating services from wetlands and coastal vegetation.

Potential management question	Associated ecosystem services	Target audience(s)
How is sea level rise affecting coastal properties?	Habitat or supporting; Regulating	General public; Municipalities; State/fed govt
What is the value of carbon in eelgrass beds?	Habitat or supporting; Regulating	General public; Municipalities; State/fed govt

[1] See also Table 4.

Table 4. Potential management questions—cultural and regulating services from water quality and clarity (freshwater and marine).

Potential management question	Associated ecosystem services	Target audience(s)
Is it safe to go swimming in the SNEP region?[2]	Cultural; Regulating	General public
Which coastal areas are most enjoyable/which locations most sought?	Cultural; Regulating	General public; Municipalities; State/fed govt
How many pounds of nitrogen does a healthy estuary remove?	Regulating	Municipalities; State/fed govt
What impacts are our stormwater measures having?	Regulating	General public; Municipalities; State/fed govt
Will the ecosystem improve if I upgrade my septic system or tie into the sewer system?	Regulating	Municipalities; General public
What are the sewering impacts on local environments?	Regulating	General public; Municipalities; State/fed govt
What are the downsides of sewering?	Regulating	General public; Municipalities; State/fed govt
What management actions (such as land use controls, green infrastructure, low impact development, best management practices, and piloted new technologies) are making a difference on nutrient and bacterial loads to coastal ponds and embayments in these four SNEP areas (Narragansett Bay, Buzzards Bay, Cape Cod, the Islands)?	Regulating	General public; Municipalities; State/fed govt

[2] See also Table 1.

Table 5. Potential management questions—cultural, provisioning, and regulating services from recreational and commercial fishing.

Potential management question	Associated ecosystem services	Target audience(s)
Is the ecosystem capable of supporting successful fisheries?	Cultural; Provisioning; Regulating	General public; State/fed govt
Can I catch fish, and what can I catch?	Cultural; Provisioning; Regulating	General public; Municipalities

Table 6. Potential management questions—value of SNEP-funded projects and programs.

Potential management question	Associated ecosystem services	Target audience(s)
What are the most successful programs–where are interventions going in and making a difference–in each of the SNEP areas?	Cultural; Habitat or supporting; Provisioning; Regulating	General public; Municipalities; State/fed govt
Are the eutrophication problems across the region improving?	Regulating	General public; Municipalities; State/fed govt

3 Inventory of current data collection and assessment of data gaps

3.1 Background and purpose

One of the first steps in addressing the challenges to implementing a common monitoring approach is to identify what indicators in the region are being monitored and what those data can tell us. This report section summarizes the findings of the Task 2A literature review of over 20 monitoring programs across the United States and the Task 4A summary of existing monitoring data in and adjacent to the SNEP region, including which entities are collecting the data and how the data can be found/accessed. The literature review and inventory included 22 programs and nearly 400 indicators. A complete report on these tasks is included in the appendix.

3.2 Inventory of programmatic monitoring in the SNEP region

The literature review and inventory revealed that, as expected, each program's monitoring goals were different, and therefore the breadth and quantity of indicators measured differed as well. Figure 2 presents an overview of indicators by monitoring category for 10 programs in and adjacent to the SNEP region. Some programs had partnerships with other organizations, NGOs, academic institutions, and volunteer groups that reduced their need to coordinate monitoring activities themselves.

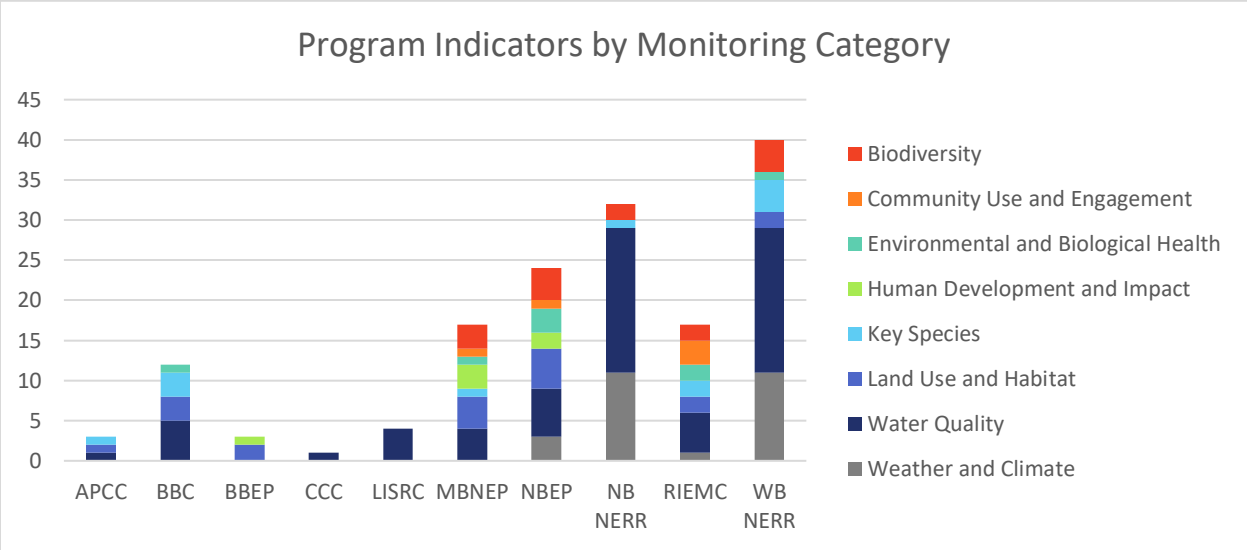


Figure 2. Program indicators by monitoring category. Indicators monitored by partner entities were not attributed to the programs above. See Appendix for details.

APCC = Associated to Preserve Cape Cod; BBC = Buzzards Bay Coalition; BBEP = Buzzards Bay Estuary Program; CCC = Cape Cod Commission; LISRC = Long Island Sound Report Card; MBNEP = MassBays National Estuary Partnership; NBEP = Narragansett Bay Estuary Program; NBNERR = Narragansett Bay National Estuarine Research Reserve; RIEMC = Rhode Island Environmental Monitoring Collaborative; WBNERR = Waquoit Bay National Estuarine Research Reserve.

3.2.1 Most common indicators and data sources

Similar to the programs examined across the United States, all programs examined in the SNEP region included water quality monitoring as part of their assessment and reporting, with about 50 percent of indicators relating to some part of the nutrient loading–algal bloom–dissolved oxygen relationship. The water quality indicator category was diverse, but while it had the greatest number of unique indicators, it essentially represents a variety of metrics being used to characterize the same core set of issues (eutrophication and human pollution sources from storms and wastewater treatment plants).

The Cape Cod Commission (CCC) is aggregating water quality data collected on Cape Cod by various entities including the Massachusetts Estuaries Project through UMass Dartmouth, the Buzzards Bay Coalition, the Center for Coastal Studies, and the Waquoit Bay National Estuarine Research Reserve (NERR) into a central repository. This effort is funded by SNEP and could be used as a template for further aggregation of water quality data across the region.

Other common indicators included land use and habitat, with an emphasis on wetlands. The most common indicators used in the SNEP region for each monitoring category are presented in Table 7.

Table 7. Top indicator in each category.

Indicator Category	Top Indicator
Biodiversity	Fish communities (6)
Community use and engagement	Shellfish (3)
Environmental and biological health	Contaminants (4)
Human development and impact	Population (2)
Key species	Eelgrass (3)
Land use and habitat	Wetlands (8)
Water quality	Nutrients (14)
Weather and climate	Precipitation (5) and wind (10)*

* Both the Narragansett Bay NERR and the Waquoit Bay NERR are part of the NERR System Wide Monitoring Program, which monitors five parameters on wind. These are listed in the database separately for each NERR. Precipitation was monitored by three programs in the region.

State and federal agencies, industry, academic institutions, and NGOs were all important providers of data to support indicators in and adjacent to the SNEP region (Table 8).

Table 8. Data sources leveraged by programs in and adjacent to the SNEP region.

Source	Frequency
Rhode Island Department of Environmental Management (RIDEM)	12
MassGIS (Bureau of Geographic Information)	5
Narragansett Bay Commission	5
Narragansett Bay NERR	5
The University of Rhode Island (URI)	5
United States Geological Survey (USGS)	5
Rhode Island Coastal Resources Management Council (RI CRMC)	4
Massachusetts Office of Coastal Zone Management (MassCZM)	3
Massachusetts Department of Environmental Protection (MassDEP)	3
Massachusetts Division of Marine Fisheries (MassDMF)	3
Massachusetts Water Resources Authority (MWRA)	3
Rhode Island Natural History Survey	3
Rhode Island Department of Health (RIDOH)	3
Save the Bay	3
NERR System Wide Monitoring Program (SWMP)	3
BayWatchers	2
URI Graduate School of Oceanography	2
Massachusetts Department of Public Health (MassDPH)	2
Narragansett Bay Fixed Site Monitoring Network	2
National Oceanic and Atmospheric Administration (NOAA) Mussel Watch	2
Provincetown Center for Coastal Studies	2
Rhode Island Geographic Information System (RIGIS)	2
United States Census Bureau (USCB)	2

Several programs discussed a need for more continuous monitoring (e.g., the Buzzards Bay Coalition and BBEP would like to see water quality stations added in the open bay). The NERR SWMP has collected data at the Narragansett Bay and Waquoit Bay NERRs since it began in 1995; Baywatchers (Buzzards Bay) was established in 1992. From the programs for which we have sampling interval information, these three have some of the smallest sampling intervals (Table 9). Water quality indicators are likely the most common continuous and long-term monitoring indicators. Bacteria are also monitored often, but only during recreation seasons, and the duration and frequency vary by program.

Table 9. Examples of high-frequency data collection in the SNEP region.

15-Minute Intervals	**(NERRs)**
Ammonium	2
Depth	4
Level	2
pH	2
Salinity	2
Sonde level	2
Specific conductivity	2
Turbidity	2
Water temperature	2
Weekly	**(Buzzards Bay Coalition)**
Nitrogen	1
Dissolved oxygen	1
Water clarity	1
Monthly	**(NERRs)**
Nitrate	2
Nitrite	2
Nitrite and nitrate	2
Dissolved oxygen	4
Chlorophyll a	2
Chlorophyll fluorescence	2
Orthophosphate	2

3.2.2 Indicators connected to ecosystem services

Nearly half of all indicators included in the full inventory draw the link between an indicator and the ecosystem service(s) it provides. In the SNEP region, however, reports and communication materials explicitly connected just over one-third of indicators to ecosystem services. And only a handful of programs identified beneficiaries or included estimates of ecosystem service values. Figure 3 presents the proportion of indicators per category that identified ecosystem services to the total indicators in each category.

In the national inventory, most of the land use and habitat and biodiversity indicators were linked to ecosystem services, while only a small percentage of water quality indicators included the connection. This tendency coincides with findings from interviews with SNEP-region program staff that many programs struggled to make the connection between water quality indicators (e.g., nitrogen) to tangible benefits or costs to the public. Additionally, these

programs almost never identified the often-negative relationship between stressor indicators across categories (e.g., invasive species, impervious surface) and ecosystem services.

Moreover, wetlands and fisheries are key issues for the SNEP region, providing services across all four ecosystem services groups and serving many beneficiaries (Table 10). Commercial and recreational fishermen were the most frequently identified beneficiaries, which aligns with fisheries being most identified ecosystem service. While indicators like nitrogen concentration and dissolved oxygen were identified as important for management and conservation efforts, fish population and wetlands are likely more tangible indicators that can be used to engage with the public.

Table 10. Common indicators in each ecosystem services group.

Common Indicators for ES Groups	
Cultural	Fish communities or fish species (9)
Provisioning	Fish communities (6)
Regulating	Wetlands (8)
Supporting/habitat	Wetlands (8)

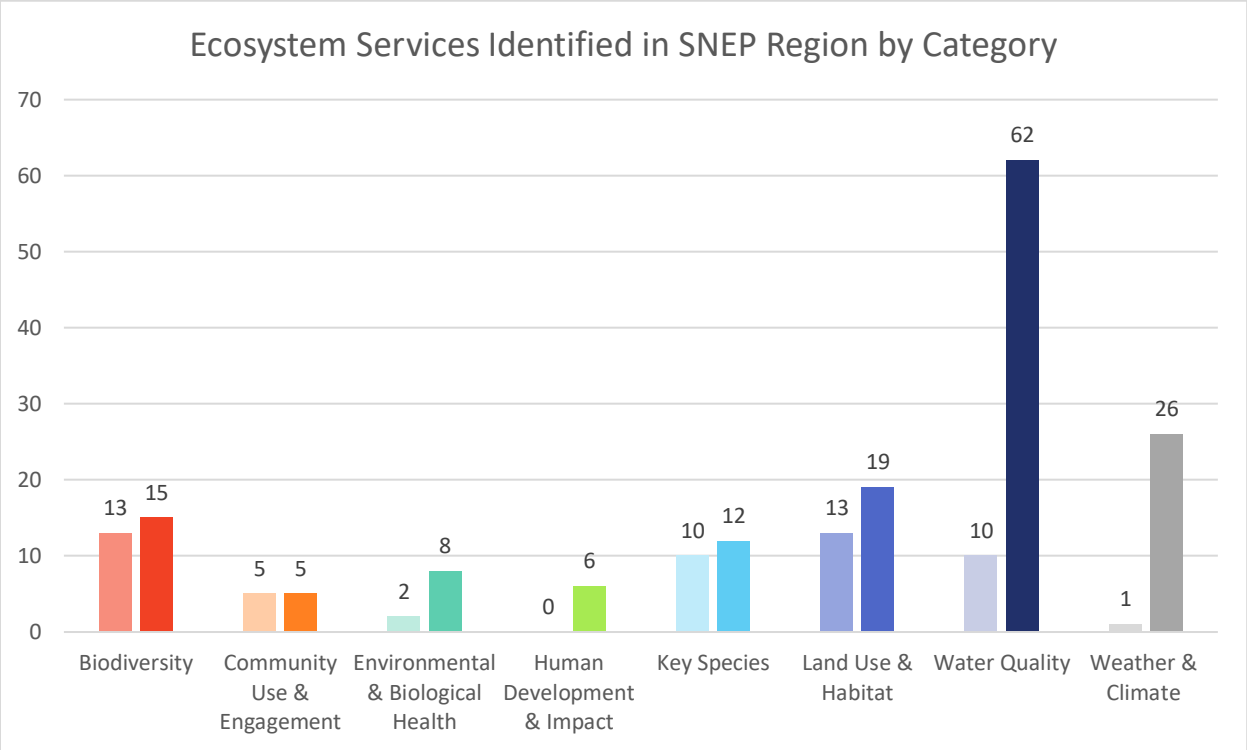


Figure 3. Total number of indicators in and adjacent to the SNEP region to which an ecosystem service was explicitly connected (left bar) compared to the total number of indicators (right bar) for each indicator category.

3.2.3 Least common indicators

According to our inventory, socioeconomic indicators were the least common indicators measured in the SNEP region. Few indicators monitor anthropogenic stressors on the surrounding ecology. Human uses are rarely monitored directly. Four programs monitor toxic contaminants, but each has a different focus (e.g., trace metals, mercury, chemical compounds such as PCBs).

Other indicators that were unique included sea level rise (reported only by the Narragansett Bay Estuary Program), shoreline erosion (Rhode Island Environmental Monitoring Collaborative), and blue carbon (Waquoit Bay NERR).

3.3 Inventory of water quality monitoring activities associated with SNEP-funded projects

Part of Task 4A was a survey and analysis of water quality monitoring conducted under SNEP-funded projects, including:

- Representative SNEP-funded projects that required monitoring over a period of time.
- The parameters monitored by the projects and the kinds of information those parameters were proposed/intended to convey.
- How long the project was monitored and how well it captured the proposed/intended information.
- Whether the project achieved its aims and continues to meet its aims, and whether monitoring is continuing after the project period is over.

Information on 46 SNEP-funded projects with water quality monitoring components was compiled from the SNEP Dashboard, project final reports, and Quality Assurance Project Plans provided by EPA. A spreadsheet (appendix) contains information for each project on data collected (parameters monitored); indicators; duration of monitoring activities (including how long after project period); data gaps, research needs, assessment needs (how well the monitoring activities capture the proposed/intended information); and whether the project achieved its aims. Limited information was available for some of the projects, especially for projects funded since 2018 that are still getting underway. Other projects in the SNEP Dashboard did not indicate whether they have monitoring components.

SNEP-funded projects' aims generally fell into one of five types:

- Establish baseline flow and water quality conditions for surface water, groundwater, and stormwater; develop an Index of Biological Integrity for surface waters.
- Identify nutrient and bacterial pollutant sources (using GIS in some cases).
- Evaluate best management practices, conventional treatments, and innovative treatments for removing pollutants (primarily nitrogen and phosphorus).
- Outreach/education.
- Investigate the effects of changing climate on watershed loading and water quality.

Most projects focused on nutrient loading, sources, and removal efficiency. The majority (63 percent) did not specify whether they had achieved their aims. Of those projects that did specify, 89 percent indicated that they did achieve their aims. Common assessment needs or future research included additional site assessments, continuous monitoring or secondary rounds of data collection, and the development of models to contextualize or improve results (e.g., hydrodynamic flow).

Projects used multiple water quality indicators. Thirty projects collected nitrogen data, 17 projects evaluated phosphorus, and 20 projects collected dissolved oxygen data. Specific projects include septic system or wastewater treatment plant upgrades/optimization, passive groundwater treatment (permeable reactive barrier) or soil amendment for nitrogen removal, and gypsum addition to a cranberry bog for phosphorus removal. Biological efforts to remove nutrients were evaluated with establishing or increasing oyster or ribbed mussel populations, harvesting the reed *Phragmites australis*, and building green infrastructure (e.g., bioretention swales and rain gardens).

3.4 Notable data gaps in the SNEP region

The appendix presents a full assessment of data gaps gleaned from the program inventory. Notable data gaps from both the program inventory and project inventory are captured here.

3.4.1 Connection to ecosystem services and beneficiaries

Few indicators are explicitly linked to ecosystem services and/or the people who benefit from healthy coastal environments. For all indicator categories, but especially water quality indicators, connections to ecosystem services and beneficiaries are a notable gap. The proposed IESF described in the next two sections could help address this gap.

3.4.2 Climate change

In the programs evaluated, weather and climate change data were lacking. The Narragansett Bay Estuary Program is the only program in the SNEP inventory that monitors sea level rise. Its report notes the lack of data available in the Bay and the "considerable uncertainty in predicting response to acidification in the estuarine environment." During interviews with SNEP-region program staff, several people acknowledged the need for more climate change and weather indicator monitoring efforts. Although multiple SNEP-funded project documents note climate change as an important topic, only 2 percent of projects monitor climate- or weather-related indicators. Furthermore, the Task 2C mapping effort revealed that over 740,000 acres (~1,150 square miles) of land in the SNEP region are classified by the Federal Emergency Management Agency as facing high or moderate risk of flooding, and over 50,000 acres (~78 square miles) are susceptible to high tide flooding (appendix).

3.4.3 Biodiversity and key species

Multiple interviewees commented on the lack of biological monitoring within their regions and cited anecdotal evidence of die-offs that monitoring efforts did not capture. Interviewees also

noted that biological indicators often resonate with the public and provide opportunities to connect ecosystem functions, habitats, and services.

3.4.4 Human impact and development

Only the three national estuary programs (Buzzards Bay, MassBays, and Narragansett Bay) within the SNEP region specifically monitor human development and impacts. These programs monitor sewer and stormwater outflows and human population. There are other indicators of human impact and development in use by programs outside the SNEP region such as changes in water use, various types of infrastructure, and dredging. While almost never identified along with ecosystem services, these indicators are often drivers of change to the local ecology. Human pollution impacts the availability of many ecosystem services, from water quality to aesthetics.

3.4.5 Community use and engagement

Community use indicators within the SNEP region are limited to the population's relationships to shellfish harvesting, which only MassBays, the Narragansett Bay Estuary Program, and the Rhode Island Environmental Monitoring Collaborative monitor. In the national inventory, community use and engagement indicators were more diverse and include volunteers, citizen science efforts, and environmental literacy. Considering most programs and several SNEP-funded projects included goals related to a public engagement or outreach component, indicators relating to that effort are lacking.

3.4.6 The Islands

The SNEP region includes the islands of Martha's Vineyard and Nantucket, but they appear to be underrepresented in the program inventory. The Buzzards Bay Coalition is the only program working within Vineyard Sound, and its reach does not encompass the entire island. Our inventory did not include a profile of the Center for Coastal Studies, which may conduct some monitoring in the vicinity of the Islands.

3.5 Subcommittees' input and recommended data collection to address gaps

On August 13, 2020, the Subcommittees were invited to a webinar to hear the results of the program (Task 2A) inventory.

Using an interactive poll that generated a word cloud of results (Figure 4), participating Subcommittee members shared their opinions on the most critical data gaps in the SNEP region. Interestingly, despite the prominence of water quality indicators in the SNEP region, several participants identified "broad scale water quality monitoring" as a critical data gap. Participants also (using various wordings) identified "connections between monitoring/indicators and ecosystem services." Biological data was another common critical data gap in the poll results.

The discussion that followed focused on the urgent need to draw connections between monitoring/indicators and public health (broadly defined and including mental/physical health

and well-being). Participants shared ideas and resources that could spark further discussion and inform SNEP's approach(es):

- SNEP could tie-in more directly with NOAA and provide tips and advice on what to do in the event of larger storm events (e.g., flooding, impact on services).
- A recent study shows that a measurable number of people get sick after heavy rains (in the Merrimack River valley): https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4559956/.
- Public health information and data are available, but not yet being tapped by this group (e.g., https://www.mass.gov/public-health-data-warehouse-phd for Massachusetts, https://health.ri.gov/programs/detail.php?pgm_id=1123 for Rhode Island).
- Another recent study provides a blueprint for including human well-being in ecosystem services assessments: https://vtechworks.lib.vt.edu/bitstream/handle/10919/47998/ES-2013-6173.pdf?sequence=1.
- The Trust for Public Land conducts research on the intersection of environmental conservation, public health, and economics: https://www.tpl.org/how-we-work/research-library.

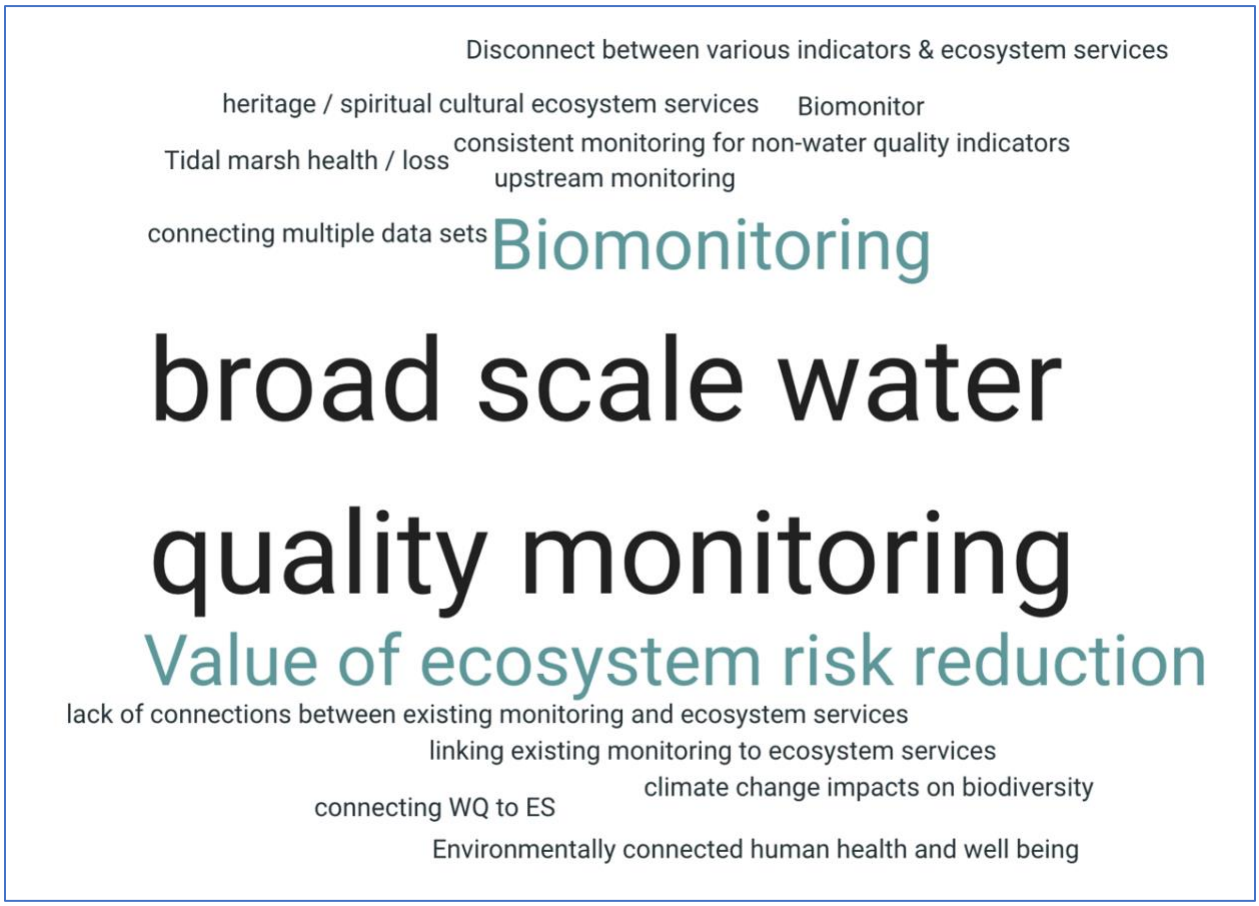


Figure 4. Subcommittee members' opinions on the most critical data gaps in the SNEP region, shown in a word cloud generated by an interactive poll during the August 13, 2020, webinar.

4 A proposed Integrated Ecosystem Services Framework

4.1 Purpose

The goal of Task 2B was to develop a functional schematic of a SNEP region IESF that would represent the interconnectivity between SNEP region ecosystem goods and services, their beneficiaries, and the indicators and metrics used to qualify and/or quantify those goods and services and their benefits.

Eventually, this framework could be used to organize the information being collected in the programmatic and project-level inventory tasks (Tasks 2A and 4A). Because the work to develop the framework occurred at the same time as the work to collect the vast amount of programmatic and project-level monitoring information available in the SNEP region, we could not directly populate the IESF with SNEP program and project data. This issue is discussed further in Section 4.4.

4.2 Developing the framework

We began developing the IESF by brainstorming structural components (including key functions and potential uses) with the SNEP Ecosystem Services Subcommittee in December 2019. Then we solicitated input on a range of ecosystem goods and services, beneficiaries, and indicators and metrics in the SNEP region from the SNEP Ecosystem Services and Monitoring Subcommittees in January 2020 to test and populate the IESF. Finally, we developed a functional IESF schematic that captures the hierarchical position of each component, as well as the connections between the components.

We developed a framework with two parts: a relational database and a functional schematic. Each component of the database is hierarchical.

- Indicators and metrics contains two groups: environmental data and social data, with additional subgroups in each of those categories.
- Ecosystem goods and services contains four groups, as described by TEEB (McVittie and Hussain, 2013): cultural services, habitat or supporting services, provisioning services, and regulating services. There are additional subgroups in each of those categories as well.
- Beneficiaries contains nine groups modeled after the EPA FEGS-CS (Landers and Nahlik, 2013): agricultural, commercial/industrial, education/research, future generations, government, non-use, recreational, residential, and subsistence. Each of those groups has subgroups.

Figure 5, below, is a snapshot of a few rows of the hierarchical database for each component. Each of the top-level components (represented by the different colors) should be read from left to right (group to subgroups) for increasing specificity. The database includes columns for up to four subgroups in case components are added in the future. For reference, equivalent FEGS-CS terminology is cross-walked with TEEB where possible.

Ecosystem Goods and Services

FEGS Scoping Group	Group (TEEB)	Subgroup 1 (TEEB)	Subgroup 2	Subgroup 3	Subgroup 4
Presence of the Environment	Cultural Service	Recreation and Mental/Physical Health	Recreation		
Presence of the Environment	Regulating Service	Moderation of Extreme Events	Drainage Basin	Natural Drainage	
Viewscapes	Cultural Service	Aesthetic Appreciation/Inspiration for Culture, Art and Design	Clean Air View		
Fauna	Provisioning Service	Food	Animals for Consumption		Fish for Consumption

Beneficiaries

FEGS Scoping Group	Group	Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4
Recreational	Commercial/Industrial	Entertainment Companies	Tour Boats		
Non-Use	Non-Use	Conservation/Advocacy Organizations			
Commercial/Industrial	Commercial/Industrial	Charter Fishing Companies			
Commercial/Industrial	Commercial/Industrial	Commercial Fishermen			

Indicators and Metrics

Group	Subgroup 1	Subgroup 2	Subgroup 3	Subgroup 4
Social Data	Financial Indicators	Recreational Dollars Spent		
Environmental Data	Climate Indicators	Flooding Extent		
Social Data	Financial Indicators	Recreational Dollars Spent		
Social Data	Financial Indicators	Commercial Fish Harvest		

Figure 5. Excerpts from the IESF relational database illustrating the group and subgroup hierarchy.

The first part of the IESF—the relational database—addresses most of the considerations raised by SNEP and the Subcommittees:

- It is hierarchical and flexible.
- It is complex, but has an expandable/collapsible network of concepts. The database includes columns for up to four subgroups in case components are added in the future.
- It uses clear, simple terminology suitable for broad audiences, specifically the conventionally accepted TEEB.
- It is relatively easily updated and maintained; a medium level of proficiency with Microsoft Excel is required to maintain and update the IESF database.
- It captures the relationships between three main components—ecosystem goods and services, beneficiaries, and indicators and metrics. (However, they are difficult to understand and interpret in the tabular database itself. SNEP and the Subcommittees noted that the framework should visualize the relationships.)
- It captures environmental indicators and social indicators. Although the majority of the indicators and metrics suggested by the Subcommittees referred to environmental data (e.g., nutrient concentrations, water temperature), Subcommittee members indicated that there are also many social/economic indicators (e.g., beach visitations, property values) that provide important information on the use of SNEP region ecosystem goods and services. To address this, "Social Data" was added as a group under the top-level category of indicators and metrics. This addition may be relevant to SNEP's goals; that is, the program may want to consider explicitly including social/economic indicators in the SNEP monitoring strategy and/or adding social/economic indicator expertise to the Monitoring Subcommittee.
- It is filterable and sortable based on focal questions or interests. The basic filter and sort functions in Microsoft Excel can be used to select, isolate, and organize subsets of the database.

The second part of the IESF—the functional schematic—could not be developed until the database was at least partially populated with example indicators and metrics, ecosystem

goods and services, and beneficiaries. We anticipated that the schematic would address a key component of the IESF: visualizing the relationships between these three components.

4.3 Testing the framework

We tested the framework by populating it with the suggestions made by the SNEP Subcommittees at the January 2020 workshop—a "wish list" of indicators and metrics, ecosystem goods and services, and beneficiaries. By adding the Subcommittees' suggested elements to the relational database, we were able to test the framework and generate a draft schematic to ensure it adequately linked ecological conditions to ecosystem services and the people who benefit, as well as highlight potential focal ecosystem conditions, functions, and/or beneficiaries.

Overall, the database was populated with about 760 relationships between SNEP region-related ecosystem goods and services, beneficiaries, and indicators and metrics. (This number of connections exceeded our expectations for what the Subcommittees might provide.) Details on the construction of the schematic, including the R code used to generate it from the relational database, can be found in the appendix. The SNEP IESF functional schematic consists of three concentric rings (Figure 6). The outermost ring contains the three main components (ecosystem goods and services, beneficiaries, indicators and metrics). The adjacent inside ring contains the "group"-level information for each of these components and the innermost ring contains the "subgroup 1" information from the IESF database. The amount of information that can be shown is limited by the smallest readable font size (i.e., we did not add inner rings beyond subgroup 1 because they would not be discernable).

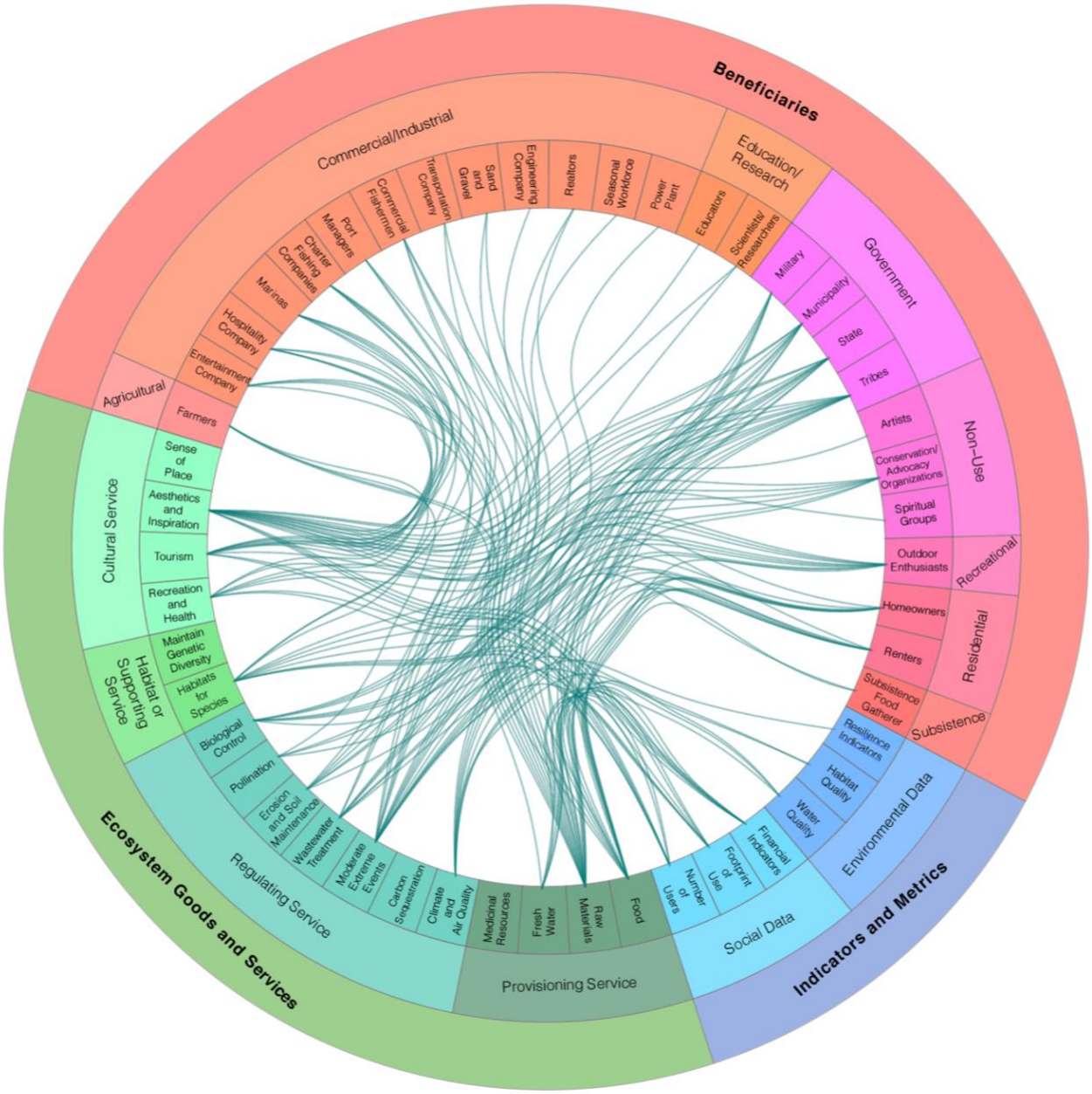


Figure 6. Conceptual SNEP region IESF functional schematic illustrating the hierarchical structure and interconnectivity of the IESF relational database components. The full test version of the database, containing about 760 elements, was used for this example.

To address this, the code that generates the functional IESF schematic has been adapted so that custom "versions" of the schematic can be generated that show only the relationships/ connections around a component or element of interest (e.g., Figure 7; additional examples provided in the appendix). This simplifies the schematic such that fewer elements clutter the diagram and relationships are clearer. Further steps to simplify the diagram could include pushing the group-level ring into the outer ring, making more room for subgroup-1-level labels.

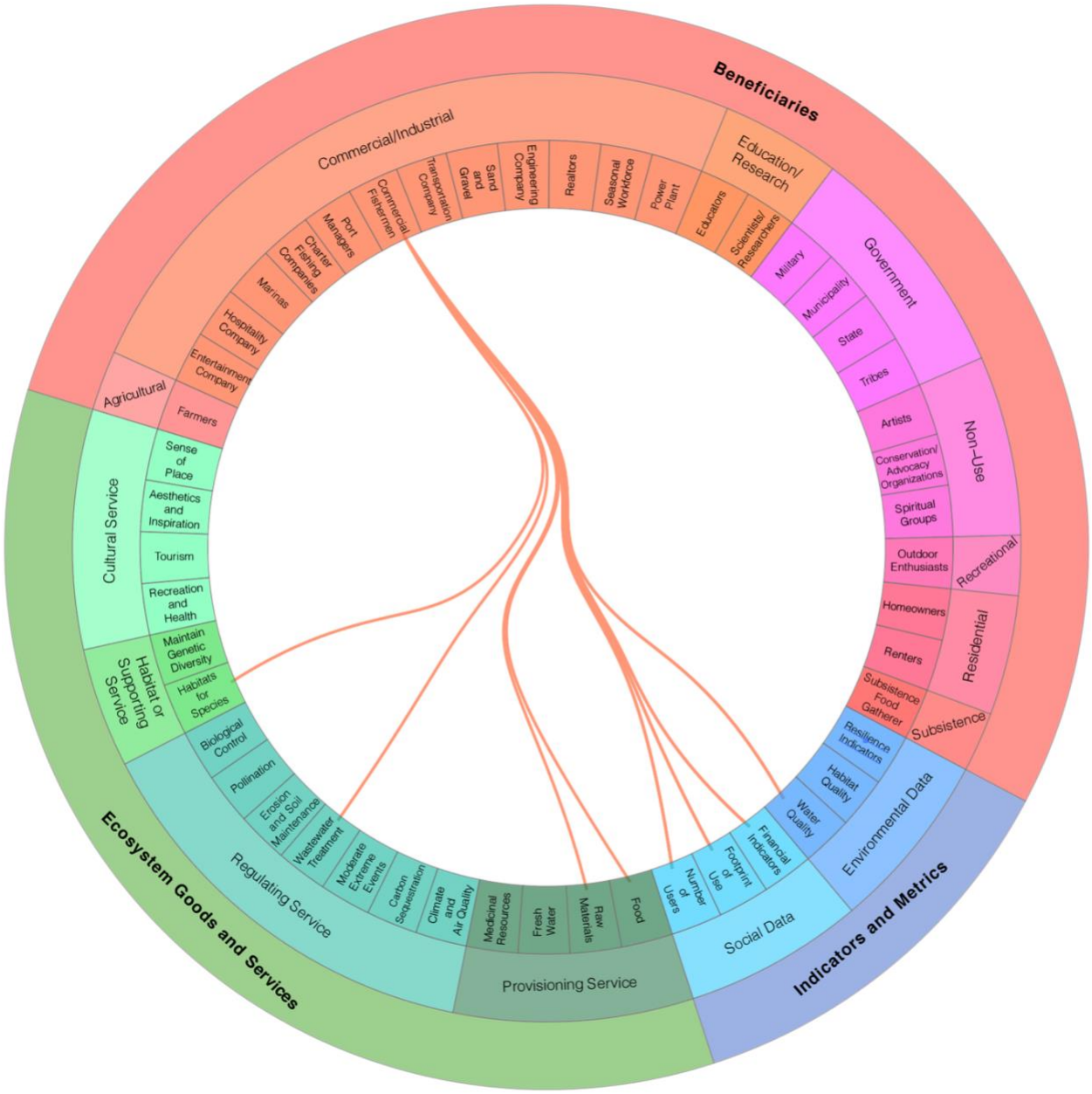


Figure 7. An example IESF schematic generated from a filtered version of the database, showing ecosystem goods and services and indicators and metrics that relate to a single group of beneficiaries: in this case, commercial fishermen.

Note that the draft schematics shown here reflect the suggestions of the Subcommittees only, not the actual indicators and metrics being measured or monitored in the SNEP region.

4.4 Next steps

An immediate next step for SNEP is to apply the framework developed here to the specific monitoring information being collected in the region. To do this, all program and project inventory data (i.e., from Tasks 2A and 4A) should be added to the IESF database using

consistent nomenclature. Any elements suggested by Subcommittee members that are not reflected in current programmatic or project-level monitoring should be kept in a separate part of the database for future use because they represent potential data gaps or areas of future work.

There is also a need to test how SNEP could use the IESF. This type of use has been discussed during this contract as "operationalization of the IESF": specific ways to use it to learn something about the ecological conditions and functions in the region and the benefits these ecological components provide to communities (qualitatively and quantitatively).

The next section describes one way in which SNEP could operationalize the IESF—a test, using a key management question suggested by SNEP Subcommittee members as a prompt. **This test will leverage all parts of this contract to demonstrate how SNEP can use the data and information collected by partner entities and lessons learned from SNEP-funded projects to explain regional trends, evaluate the success of new technologies and approaches, guide broad management decisions, and monitor and assess the effects of those decisions.**

5 Using the IESF to develop monitoring strategies that address key management questions

This section walks through a process for using the IESF to develop monitoring strategies that address an example management question. It also suggests ways to communicate how SNEP is attempting to answer the management question by directing funding toward studies or monitoring on this topic.

5.1 Step 1: Identify a management question

"What is the value of a beach day locally?"

We chose a question focused on beaches for a number of reasons.

First, the Task 4D Twitter analysis (appendix) revealed that "beach" was the most often-tweeted word from our selection of 22 nature-based coastal/ocean words (Figure 8).

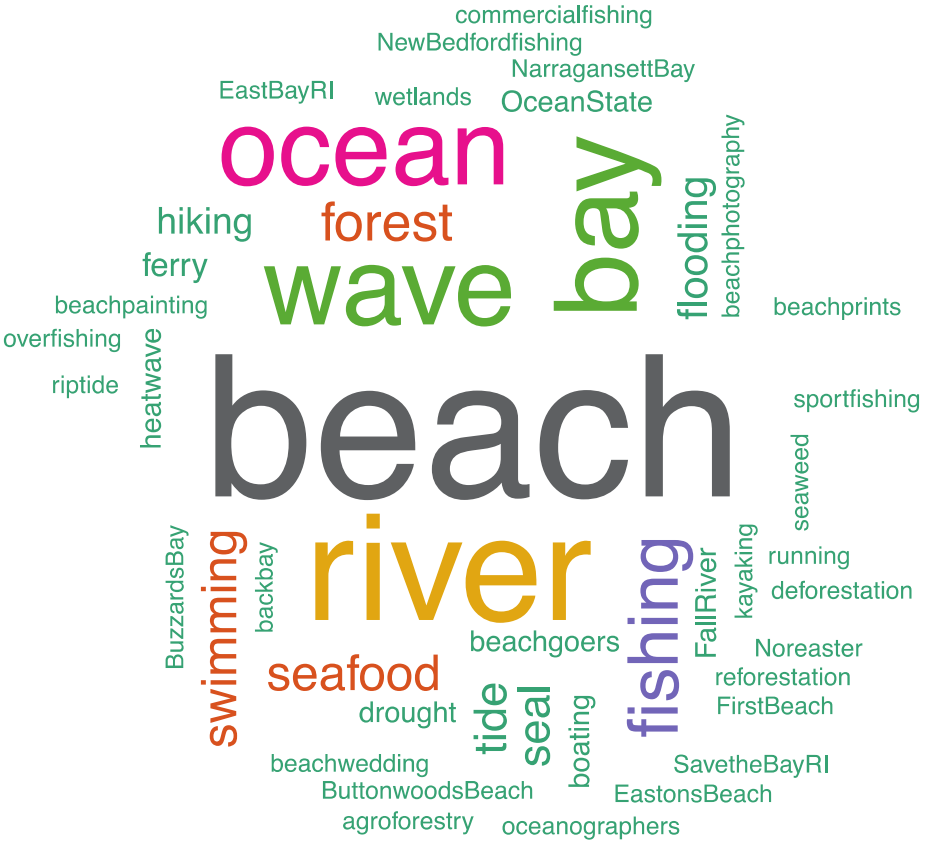


Figure 8. A word cloud captures the most common words in SNEP-region tweets from the list of words we monitored in Task 4D.

In addition, the results of the Task 2A monitoring program literature review and inventory showed that although indicators related to water quality and beach closures are well-represented in the monitoring programs in the SNEP region, a connection to community use and economic indicators is lacking. Indeed, the RI Monitoring Collaborative, Narragansett Bay

Estuary Program, and Buzzards Bay Coalition each use presence or concentrations of bacteria and/or resulting beach closures as an indicator and describe links to recreational uses and public health in the narrative parts of their reports/communication materials. However, these programs do not track the resulting impact of bacterial impairment on realized beach use or revenue for municipalities and states. Furthermore, Subcommittee members discussed the relative gap in monitoring indicators representative of cultural ecosystem services during the August 2020 webinar and expressed interest in learning more about available data and information to fill this gap. The question that we chose for this example was articulated by Subcommittee members during workshops held in 2019 (see Section 2.2, Table 1). Finally, the Task 5 pilot valuation (appendix) focused on characterizing the non-market value (i.e., the dollar amount an individual would be willing to pay) of beach visits at 19 upper Narragansett Bay beaches and the non-market value lost when those beaches were closed due to poor water quality. The work done for Task 5 allows us to demonstrate the complete workflow for operationalizing the IESF.

5.2 Step 2: Identify IESF components relevant to the question

The IESF database makes links between and among indicators and metrics, ecosystem goods and services, and beneficiaries.

5.2.1 Identify ecosystem goods and services relevant to the question

From Table 1 in Section 2.2, we know that cultural services and regulating services are relevant to characterizing the value of a beach day locally, so we can use those ecosystem goods and services groups to begin exploring the IESF database. In the database we will find indicators and metrics that are connected to those ecosystem goods and services, as well as a list of beneficiaries who represent the affected communities and to whom communication materials could be targeted.

Each of these groups of ecosystem goods and services was expanded using the information in the IESF database. Each bullet and sub-bullet below represents an ecosystem service (more specific services are identified deeper into the hierarchy) provided by beach visits.

Cultural services from beach visitation and other water-related recreation

- Recreation and mental/physical health
    - Human health
        - Physical well-being
    - Peace of mind
        - Emotional well-being
        - Relaxation
    - Recreation
        - Recreational boating
        - Recreational fishing

        - Recreational swimming
        - Wildlife watching
- Tourism
    - Beach
    - Clean beach view
    - Clean ocean view
- Aesthetic appreciation/inspiration for culture, art, and design
    - Appreciation of nature
    - Clean beach view
    - Clean ocean view
- Spiritual experience and sense of place
    - Beach
    - Clean beach view
    - Clean ocean view

Regulating services required to maintain beach visitation

- Wastewater treatment
    - Nutrient extraction
    - Filtration of human and animal waste
    - Suppression/elimination of pathogens
- Moderation of extreme events
    - Moderation of extreme rainfall events
- Erosion prevention
    - Shoreline stabilization

5.2.2 Identify beneficiaries relevant to the question

Next, we can use the IESF database to identify potential beneficiaries of the services listed above. Identifying beneficiaries will help build strategies for communicating status and trends and inspiring local/individual action. Knowing the audience(s) for particular elements of information will also help build public support for and trust in management actions or interventions. Each bullet and sub-bullet below represents a beneficiary group (more specific beneficiaries are identified deeper into the hierarchy).

Beneficiaries of the cultural and regulating services related to beach visits:

- Commercial/industrial
    - Hospitality company
    - Recreation equipment rental company

    - Restaurants
    - Realtors
    - Wastewater treatment facility
- Residential
    - Homeowners
    - Renters
- Education/research
- Future generations
- Government
    - Municipalities
    - Tribes
- Non-use
    - Artists
    - Spiritual groups
- Recreational
    - Recreational fishermen
    - Recreational swimmers
    - Beach goers
    - Wildlife watchers/listeners

5.2.3 Identify indicators and metrics relevant to the question

The final remaining components of the IESF database are indicators and metrics. Using the ecosystem goods and services and beneficiaries to filter the IESF database, we can identify relevant indicators and metrics that can be used to characterize and monitor 1) the ecosystem's ability to provide the services (i.e., environmental indicators and metrics), and 2) the degree to which the community is benefiting from the service (i.e., social and economic indicators and metrics).

If the IESF database were fully populated with information from the Task 2A inventory, the outputs of this type of query would represent actual data and information being collected in the SNEP region that can be synthesized to answer the management question. Since this is not yet the case, we identify SNEP-region data pertinent to these indicators and metrics in the next step.

Environmental indicators and metrics

- Water quality
    - Bacterial counts
    - Beach closure days

    - Duration of harmful algal blooms
    - Toxic algal bloom occurrence
    - Fish kills
    - Water clarity
    - Wastewater treatment facility loading

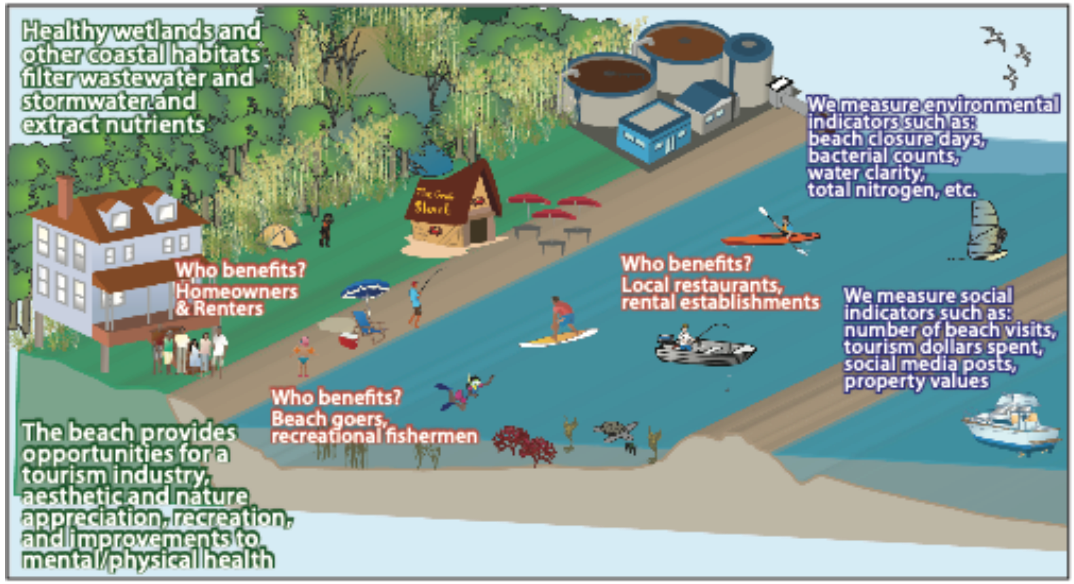
Social and economic indicators and metrics

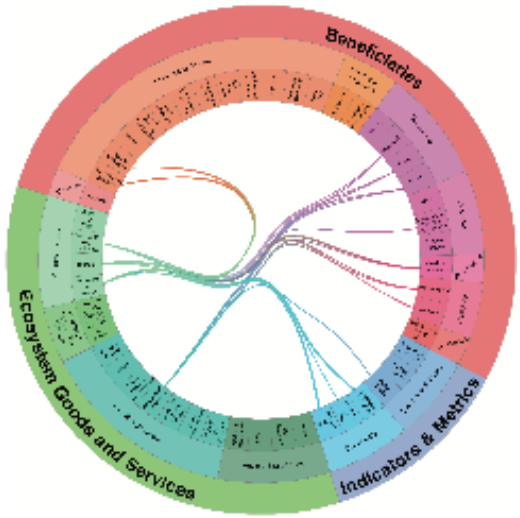
- Number of users
    - Beach visits
    - Recreational fish landings
    - Nature-related social media posts
    - Picture uploads
- Footprint of use
    - Number of beach access points
- Financial indicators and metrics
    - Recreational dollars spent
    - Tourism revenue

5.2.4 Visualize connections and links among ecosystem goods and services, beneficiaries, and indicators and metrics

The lists in the preceding sections do not convey the connections and links between and among IESF elements related to the value of a beach day. The IESF database makes these connections explicit, but the database itself is not a visualization tool. The IESF schematic does visualize these relationships and connections but is still quite technical for a general audience. The schematic could be supplemented with a conceptual diagram (Figure 9, next page) developed by an end user (e.g., SNEP) that is tailored for conveying this information to the public. This schematic and diagram together would help convey the ecosystem function, services, indicators, and beneficiaries relevant to the issue of beach visits—and more—to an audience broader than the schematic alone. They could be edited to capture the current scientific understanding as well as community priorities and environmental values (IAN, 2020).

What is the cost of a beach closure locally?





Indicators and Metrics how we measure the presence or use of ecosystem goods and services		Ecosystem Goods and Services the benefits people obtain from nature		Beneficiaries the types of people who benefit from nature	
Environmental Data	***Social Data***	***Regulating Services***	***Cultural Services***	***Government***	***Recreational***
WATER QUALITY	NUMBER OF USERS	Wastewater Treatment	Recreation and Mental/-Physical Health	Municipalities	Recreational fishermen
Bacterial counts	Beach visits	Moderation of Extreme Events	Tourism	Tribes	Recreational swimmers
Beach closure days	Recreational fish landings	Erosion Prevention	Aesthetic and Nature Appreciation	***Residential***	Beach goers
Duration of Harmful Algal Blooms	Nature-related social media posts		Spiritual experience and sense of place	Homeowners	Wildlife watchers/listeners
Toxic algal bloom occurrence	Picture uploads			Renters	***Non-Use***
Fish kills	FOOTPRINT OF USE			***Commercial/Industrial***	Artists
Water clarity	Number of Access Points			Hospitality companies	Spiritual groups
Wastewater treatment facility loading	FINCANCIAL INDICATORS			Recreation equipment rental companies	***Education/Research***
	Recreational dollars spent			Restaurants	***Future generations***
	Tourism revenue			Realtors	
				Wastewater treatment facilities	

Regulating Services are the services that ecosystems provide by regulating the quality of air, soil, and water, or by providing flood and disease control.

Cultural Services are the non-material benefits people obtain from nature. They include recreation, aesthetic enjoyment, physical and mental health benefits and spiritual experiences. They contribute to a sense of place, foster social cohesion and are essential for human health and well-being.

Figure 9. Conceptual diagram and IESF schematic that illustrate the links between and among indicators and metrics, ecosystem goods and services, and beneficiaries related to characterizing the value of a beach closure.

5.3 Step 3: Filter and extract relevant information on regional monitoring

We queried the program inventory described in Section 3 (Task 2A) to find data being collected in the region that relate to the environmental and social and economic indicators and metrics listed above. The resulting output is shown in Table 11.

Table 11. Monitoring information extracted from the Task 2A inventory that relates to beach visits and closures. (C = cultural; P = provisioning; R = regulating; S/H = supporting and habitat.)

Program	Indicator	Indicator Description	Ecosystem Services				Data Collected	Data Source	Sampling Interval
			C	P	R	S/H			
MassBays National Estuary Program	Bacteria	Concentration of fecal bacteria in the water	✓	x	x	x	Percent of water quality samples that exceed the bacteria standard; beach water quality data	MassDPH	N/A
MassBays National Estuary Program	Harmful algal blooms	Cause and frequency of red tides (*Alexandrium fundyense*)	x	x	✓	x	Maximum levels of paralytic shellfish poisoning toxicity; shellfish closures due to red tide	MWRA; WHOI	N/A
Buzzards Bay Coalition	Bacteria	Amount of bacteria	✓	x	x	x	Acreage of shellfish bed closures	N/A	N/A
Association to Preserve Cape Cod	Cyano-bacteria	Frequency of blooms	x	x	✓	x	Cyanobacteria scums; microcystin concentrations; turbidity; nutrient data	N/A	N/A
Narragansett Bay Estuary Program	Bacteria	Presence of bacteria that indicate the presence of human pathogens in the water	✓	x	x	x	Total extent of waters; state water quality assessments	National Hydrology Dataset	N/A
Narragansett Bay Estuary Program	Beach closures	Number of beach closures due to bacteria or other contamination	✓	x	x	x	Number of beach closure days; total beach closure events	RIDOH; MassDPH	N/A
Rhode Island Environmental Monitoring Collaborative	Bacteria	Presence of pathogens in water	✓	x	x	x	Bacteria genera and enterococci in cfu/100 mL	RIDOH; Save the Bay; Clean Ocean Access	Twice a week, biweekly, or monthly from May to September
Rhode Island Environmental Monitoring Collaborative	Harmful algal blooms	Presence and identification of cyanobacteria species	x	x	✓	x	Phytoplankton cell counts; qualitative estimate of cell densities of cyanobacteria	RIDEM; RIDOH	April–November in shellfish growing areas and open water; 6–12 times per year depending on the location; advisory triggers biweekly monitoring

5.4 Step 4: Determine the compatibility of the available data for answering the question, along with any gaps

The table above represents the current active monitoring captured in the Task 2A inventory that could be relevant to answering, "What is the value of a beach day locally?" Several programs monitor environmental indicators and metrics, such as bacteria, cyanobacteria, and harmful algal blooms, but only the Narragansett Bay Estuary Program compiles beach closures due to bacteria or other contamination from both Rhode Island and Massachusetts data sources.

Although none of the programs in the current inventory appear to monitor social and economic indicators related to beach closures, we know from work on the Task 5 pilot valuation that the EPA Office of Research and Development, Atlantic Coastal Ecosystem Sciences Division, has been compiling and analyzing information to characterize patterns in coastal resource use and economic impact for the last several years (Wainger and Mazzotta, 2011; Jewhurst and Mazzotta, 2016; Mazzotta et al., 2016; Lyon et al., 2018; Mulvaney et al., 2020; Merrill et al., 2020). We can therefore use their data and information to plug this data gap.

5.5 Step 5: Choose regional indicators that address the question and analyze them

The Task 5 pilot valuation study used environmental indicators and metrics (beach location, saltwater versus freshwater, beach length, and beach closure data) and social and economic indicators and metrics (consumer surplus value for beaches, beach visits) to estimate the non-market value of a beach day and therefore the cost of a beach closure for 19 beaches in Narragansett Bay. "Non-market value" refers to the dollar amount an individual would be willing to pay for a quality beach day beyond the market value they already pay for a beach day (e.g., transportation costs, parking fees, concessions).

Focal beaches in this study were chosen based on their proximity to communities of concern, their history of severe water quality impacts, as well as recent improvements to improve water quality. Fourteen of the beaches were identified as "high concern" in the *State of Narragansett Bay and Its Watershed* technical report (NBEP, 2017) and five were "low concern."

The study found that in 2018, 76 total closure days among the 19 beaches led to an aggregate loss of close to $883 thousand in non-market value, and 24 total closure days in 2019 led to an aggregate loss of around $182 thousand. These losses do not include the direct values lost from visitors' spending on parking fees, concessions, or other expenditures. A map of the beaches and their aggregate non-market losses due to closures between 2018 and 2019 is shown in Figure 10 (and an interactive version of this map can be viewed in the IESF Viewer).

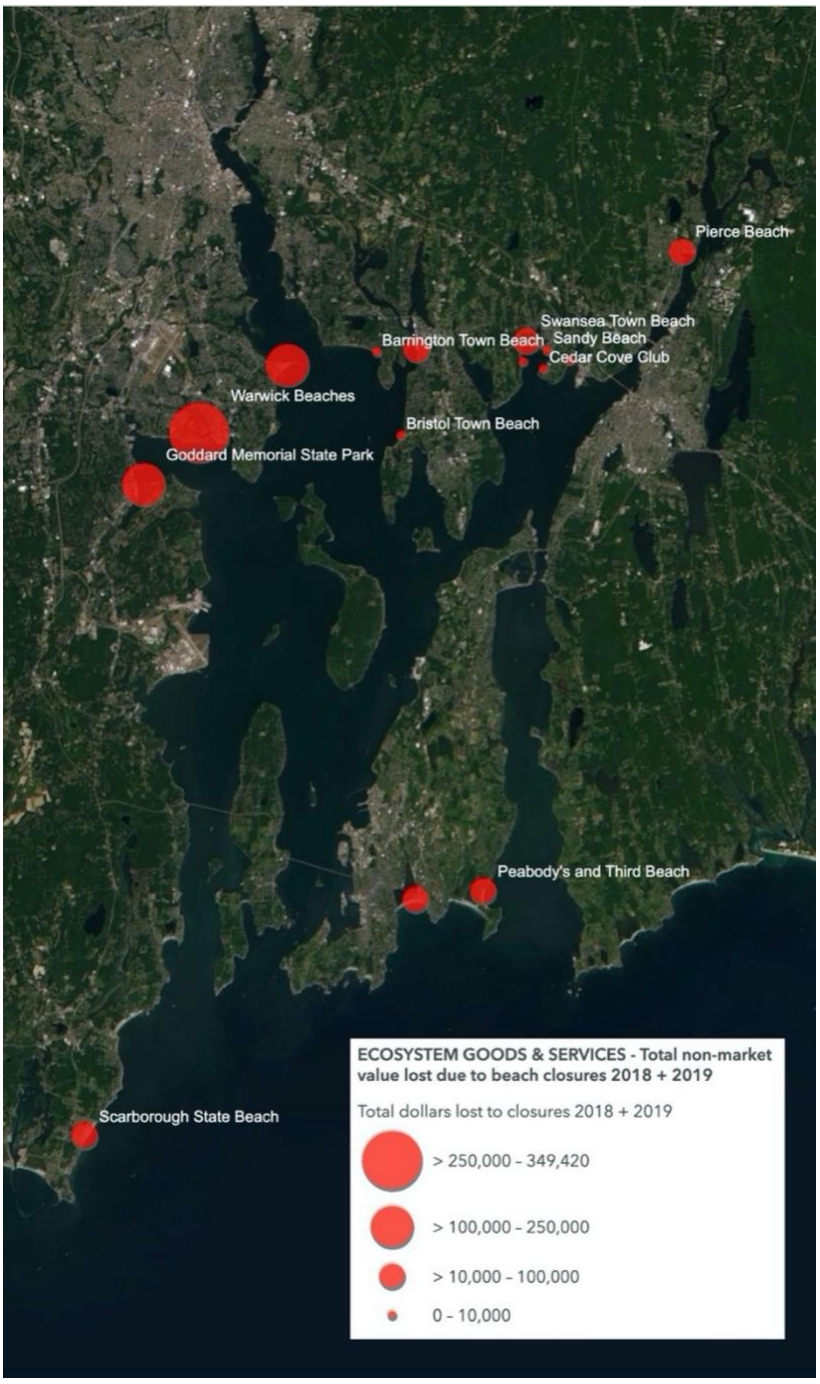


Figure 10. A map from the IESF Viewer (Task 2C) that shows the value lost due to beach closures at 19 SNEP-region beaches in 2018 and 2019.

Interesting results and lessons learned

The entire Task 5 pilot valuation report is included in the appendix. Some particularly interesting results and lessons learned are shared here:

- The exact value of a beach closure depends on the particular beach, due to both the variations in willingness-to-pay for different kinds of beaches and the visitation

potential/capacity of those beaches. A single closed day at a small community beach (e.g., Sandy Beach in Swansea, Massachusetts) could represent an average loss of ~$2,000 per day, whereas a single closed day at a larger beach in a popular vacation destination (e.g., Easton's and Atlantic Beach in Newport, Rhode Island) could represent an average loss of ~$30,000/day.

- Few beaches collect beach visitation data, and some only maintain annual or monthly summaries (making it impossible to examine daily patterns). The observed visitation data rarely take the form of actual visits and are instead estimated by counting cars or the number of beach passes sold.
- Estimates of aggregate beach day value are highly dependent on how visits are calculated, estimated, or modeled. For example, RIDEM staff assume 3.2 people per car at Scarborough Beach and apply this assumption to car counts to estimate total visits per day. RIDEM's methods resulted in total values $4–$5 million (3–5 times) higher each year than the estimates generated by the beach visitation model applied in Task 5.
- According to cell phone origin data, the majority of the visitors to upper Narragansett Bay beaches are native to the state where the beach is located. The exception is Barrington Town Beach, whose visitors were largely from Massachusetts. The majority of visitors to Easton's and Atlantic Beach in Newport, Rhode Island, are from out of state.
- In upper Narragansett Bay, the majority of visitors are native to the county or are residents of the neighboring county of the beach they are visiting (e.g., visitors to Kent County beaches visitors are largely from Kent County and neighboring Providence County), but that does not hold true for all beaches (e.g., only about 25 percent of Scarborough State Beach visitors are from Washington County).

5.6 Step 6: Highlight SNEP-funded work in the region that is relevant to the question and/or contributes to answering it

SNEP-funded projects are excellent resources to tap for thinking about management questions. In the Task 5 pilot valuation, we were able to use results from a SNEP-funded project to think about the implications of beach closures and potential management actions.

We examined the "Sheffield Cove Innovative Stormwater and Pathogen Controls" project (Gray, 2019), which—though it does not involve a beach—provides an example of effective management actions and their implementation costs. This project was funded by the New England Interstate Water Pollution Control Commission, the Narragansett Bay Estuary Program, and EPA. Sheffield Cove, in Jamestown, Rhode Island, had a history of exceeding bacterial count benchmarks, particularly after rain. Accordingly, RIDEM closed the cove to shellfishing. After identifying potential bacterial sources, a plan was developed for green infrastructure best management practice (BMP) that included the installation of dry swales and sand filters to trap runoff from the road and upgradient residential areas. The plan also included pet waste management education, since pet waste bacteria was identified during the bacteria sampling. The BMP was projected to reduce the net loading of bacterial colonies per year by 26 percent and the total project cost was $118,200 (NBEP, 2020).

In 2018, Goddard Memorial State Park lost around $237 thousand due to 10 closure days, Warwick Beaches lost over $349 thousand due to 11 closure days, and Conimicut Point Beach lost close to $178 thousand due to 14 closure days. If a BMP similar to the one implemented for Sheffield Cove could reduce the closures at any of these beaches by even 10 percent (a deliberately low assumption), the non-market savings would range from about $18,000–$34,000 per year with a non-market value "payoff" within about 3.5–6.5 years. A 20 percent decrease would halve this time to payoff; a 100 percent decrease—the best-case scenario—would produce an immediate payoff.

To leverage SNEP-funded projects further in communication materials related to addressing management questions, we can query the SNEP Dashboard or Task 4A project inventory to list projects that measured indicators and metrics relevant to the question. For example, a quick search reveals two additional projects that may yield useful information:

- "Stormwater Pathogens—Find it and Fix it: A Project to Identify Pathogens at Easton's Beach" (Clean Ocean Access, City of Newport RI, City of Middletown RI).
- "Building Large-Scale Capacity for the Rapid Detection of Bacterial Contamination in Coastal Waters" (Rhode Island Department of Health).

6 Next steps toward developing a SNEP monitoring framework

To continue to hone IESF operationalization and workflow, SNEP should consider the following next steps.

First, the IESF database could be updated to include the monitoring information and indicator categories from the Task 2A/4A inventory. Adding the monitoring information will allow users to filter and extract information about regional monitoring for any management question, and the categories add another point of entry for IESF users and could communicate the diverse reach of ecosystem goods and services on society and the environment. Elements suggested by Subcommittee members at the January 22 meeting that are not reflected in current programmatic or project-level monitoring should be kept in a separate portion of the database for future use. These suggestions (because they represent elements not currently being measured in the SNEP region) could represent data gaps or areas of future work.

Relatedly, the indicator categories could be revised as program priorities and monitoring activities change. Categories allow the database to be easily searched to address key questions about monitoring the region. Updated categories compatible with SNEP goals will make for easier use of the inventory.

This report provides several options to SNEP for prioritizing indicators and metrics. First, SNEP could prioritize indicators and metrics by adopting the most commonly measured indicators in the region, as described in Section 3.2.1 (Table 7). Or SNEP could prioritize indicators and metrics using the inventory results in some other way. Alternatively, SNEP could prioritize indicators and metrics by first prioritizing management questions or key issues in the region and then following the suggested workflow demonstrated in Section 5.

To advance this last option, SNEP could prioritize a set of management questions that could be addressed using data and information in the region and reported in a consistent way using the IESF workflows demonstrated here. The example in Section 5 of this report could then be repeated for each prioritized management question. In addition, SNEP could iteratively improve the workflow for each prioritized management question through time. Using the lessons learned from the workflow provided in Section 5 as an example, SNEP could seek to improve the data streams and methods to estimate the value of a beach day (i.e., by developing best practices for documenting beach visits or funding more complete and consistent beach visit counts) or tweak the assumptions of the models used. Furthermore, future work could examine other aspects of beach value, such as the value toward coastal protection and habitat provided by healthy dune vegetation and stable dunes. In this way, estimates of the value of beaches in the SNEP region will continue to improve over time. If each prioritized management question could be addressed in a similar manner, SNEP could gradually build a robust set of indicators and metrics, approaches, and communication products centered on the services provided by coastal ecosystems in the SNEP region.

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Appendix