Task 2.A. Results: Literature Review of Indicators and Metrics in the United States and the SNEP Region

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1. Introduction

Complex coastal and transitional ecosystems, which are abundant in the SNEP region, face many pressures including climate change, coastal erosion, overfishing, land use/land cover changes, and pollution. One of the first steps to addressing these pressures and their effects on ecosystem services is to identify what indicators in the region are being monitored and what that data can tell us. Consistent monitoring efforts can lead to robust data sets illustrating changing conditions and emerging issues.

The following report reflects the work we completed for Subtask 2.A. and Subtask 4.A., which we ultimately merged into one task with two phases. Subtask 2.A. (Phase 1) charged us with gathering information on the types of ecosystem services provided by complex coastal regions and how entities have measured and tracked this information. For this task, we conducted a literature review of over 20 monitoring programs across the United States (U.S.) and collected information on ecosystem services, indicators, and metrics, and compiled them into a filterable and sortable inventory. While Subtask 2.A. focused on a broad geographic scope, many Subcommittee members expressed that they hoped to see more programs in and adjacent to the SNEP region included in the initial review. Furthermore, Subcommittee members felt that in order to guide SNEP in defining monitoring goals and building an assessment program, they wanted to know what data other entities in the SNEP region were measuring to both avoid duplication and build on existing efforts.

Fortunately, Subtask 4.A. (Phase 2) tasked us with developing a summary of existing monitoring data in the SNEP region, including which entities are collecting the data and how the data can be found/accessed. Using the framework created for Subtask 2.A., we expanded our literature review to include additional information on beneficiaries, data collection, data sources, and more for ten programs in the SNEP vicinity.

This report summarizes the findings from Phase 1 and Phase 2 of the literature review inventory and highlights key trends and takeaways. Section 2 describes the methods used to conduct the literature review and outlines how we organized and synthesized the data collected. Sections 3 and 4 summarize the findings of each phase of the literature review and identify common indicators, data gaps, and emerging indicators for the nation-wide literature review. Section 4 also goes into further detail for Phase 2, assessing qualitative trends across programs in the SNEP region. Section 5 presents major conclusions from the findings in Sections 3 and 4 and puts forth recommendations for future applications in which SNEP could use this information.

2. Literature Review Methods

To gather data for the literature review, we used publicly available documents from various monitoring entities across the country. These monitoring programs included local and regional government agencies, nonprofit organizations, federally funded programs such as National Estuarine Research Reserves (NERR) and National Estuary Programs (NEP), and more. Most of these programs produce a product–such as a “State of the Estuary” report or progress report card–that summarizes indicators measured and progress made toward the program’s goals. Table 1 presents the 22 programs included in the literature review throughout both phases of research.

Table 1. Programs Included in the Literature Review	
Programs Included in Phase 1 Only	**Programs Included in Phase 1 and Phase 2**
America's Watershed Initiative (AWI)	Association to Preserve Cape Cod (APCC)
Chesapeake Bay Program (CBP)	Buzzards Bay Coalition (BBC)
Delaware Estuary Program (DEP)	Buzzards Bay National Estuary Program (BBNEP)
Lake Champlain Long-term Monitoring Project (LC LMP)	Cape Cod Commission (CCC)
Maryland DNR Accounting for Maryland's Ecosystem Services (MES)	Long Island Sound Report Card
National Aquatic Resource Surveys	MassBays National Estuary Program (MBNEP)
National Estuarine Research Reserve System Wide Monitoring Program (SWMP)	Narragansett Bay Estuary Program (NBEP)
NY-NJ Harbor and Estuary Program (NY-NJ HEP)	Narragansett Bay National Estuarine Research Reserve (NB NERR)
Piscataqua Region Estuaries Partnership (PREP)	Rhode Island Environmental Monitoring Collaborative (RIEMC)
Puget Sound Partnership (PSP)	Waquoit Bay National Estuarine Research Reserve (WB NERR)
San Francisco Estuary Partnership (SFEP)	
Tampa Bay Estuary Program (TBEP)	

As we researched each program, we recorded information in an inventory, which we streamlined and standardized once all data collection was complete.

During Phase 2, we also conducted several interviews with monitoring programs in and adjacent to the SNEP region. These included:

- Association to Preserve Cape Cod
- Buzzards Bay Coalition
- Buzzards Bay National Estuary Program
- Cape Cod Commission
- MassBays National Estuary Program
- Waquoit Bay National Estuarine Research Reserve

Since these organizations represent most of the existing monitoring efforts currently underway in the region, the interviews helped us glean additional information about their data collection efforts not available on their websites or in published materials. We also asked the organizations qualitative questions about data gaps and needs, long-term monitoring goals, region-wide monitoring priorities, and communications strategies. The interviews helped supplement the quantitative data gathered in the inventory and solidify some of our conclusions and recommendations.

Inventory Organization

From the beginning, we recognized that organizing and standardizing the inventory would be a challenge. While we were able to identify commonalities among the reports and pull out the information relevant to this project, each monitoring program is unique, and there is no "one size fits all" approach to monitoring ecosystem health.

During the data initial collection effort, to maintain the integrity of each report, we included information in the manner that the report presented it. Some programs did not fit as neatly into the categories as others. For example, the National Estuarine Research Reserve System and the Lake Champlain Long-term Monitoring Project focus on directly measuring quantitative data, while most other programs use existing datasets and studies to identify long-term trends and explain the benefits that each indicator provides to the ecosystem and to people. Furthermore, while many indicators can be connected to many ecosystem services and beneficiaries, we only included the ecosystem services and beneficiaries the program mentioned.

The initial data collection effort yielded nearly 400 indicators across all programs. To keep the inventory concise and more easily searchable, we went through the indicators and streamlined indicator names based on metrics and data collection. For example, "wetlands", "coastal wetlands", "saltmarsh" and "freshwater wetlands" were all classified as "wetlands-estuarine/marine" or "wetlands-freshwater".

Additionally, some indicators had relatively vague names that we changed to match other indicators that collected similar data. For instance, we changed "saltwater beach water quality" to "bacteria (saltwater beach)" as that indicator only looked at concentration of bacteria in the water. We made equivalent changes when metrics were the same or similar, to better compare indicators across programs.

Next, to effectively distinguish trends across all programs, we created categories to represent broader monitoring themes. Organizing the indicators by these themes made filtering and analyzing them easier. Table 2 presents the eight monitoring categories and includes the criteria used to designate indicators into each category along with example indicators. Some indicators arguably fit into multiple monitoring categories. In these instances, we also looked at the information about the indicator's ecosystem function and the data collected to determine the category. Ultimately, we used this categorization to analyze the inventory for common indicators and metrics, emerging themes, and potential data gaps within the SNEP region.

Table 2. Indicator Monitoring Categories		
Category	**Types of Indicators Included**	**Examples**
Biodiversity	Assess broader ecosystem health by monitoring multiple species or threats to biodiversity.	Stream invertebrates, diadromous fish populations
Community Use and Engagement	Assess human population and interactions with the ecosystem(s).	Citizen science, shellfish landings
Environmental and Biological Health	Assess non-water environmental quality and species health.	Mercury in fish, toxins in sediment
Human Development and Impacts	Monitor the built environment and human pollution.	Combined sewer overflows, water use
Key Species	Relate to a specific species which is integral to ecosystem services or health.	River herring, lobster
Land Use and Habitat	Measure land use, cover, or habitat area.	Public access, conservation lands, wetlands
Water Quality	Measure physical, chemical. or biological contents in the water.	Total nitrogen, bacteria concentration
Weather and Climate	Measure meteorological and climate conditions, including climate change impacts.	Air temperature, extreme events

3. Phase 1 Results

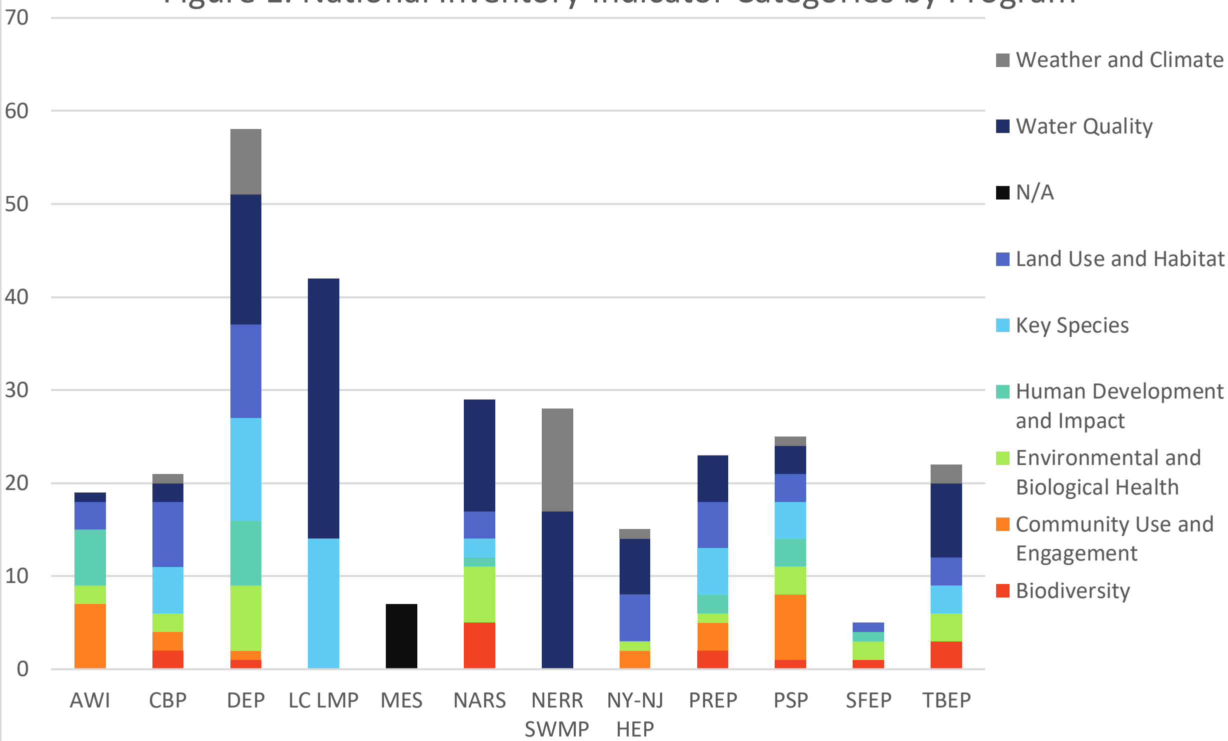
The following two sections present the results of our analysis. This section includes the results from Phase 1, the national inventory. While some of the SNEP region programs were included in the Phase 1 inventory, the analysis for Phase 1 excludes the SNEP region programs, which could skew the results when identifying gaps and comparing the region to other programs. The national inventory focuses on a broad range of monitoring programs across the U.S., from the Puget Sound to the Mississippi River to Tampa Bay. It includes nearly 300 indicators.

Common Indicators

Figure 1 presents the number of indicators in each monitoring category per program. Each indicator belongs to only one monitoring category (see Table 2 for definitions). Seven entries were not classified, as Maryland's reporting system quantifies ecosystem services without indicators.

The most common indicators for each monitoring category are listed in Table 3. Not all the indicators have the exact same name, but we grouped them together based on the data collected and indicator description for this table. Specifically, each program collected nutrient data differently.

Figure 1. National Inventory Indicator Categories by Program



Water Quality

All programs in the national inventory, except two, reviewed and monitored water quality indicators. Within water quality indicators, nutrient data is collected most often. Nutrient data metrics varied across programs, but they are all connected to a causal relationship with other commonly used water quality indicators: dissolved oxygen (DO) and chlorophyll. Chlorophyll and DO are associated with human impacts (nutrient loading), the potential for algal blooms due to loading, and the resulting poor water quality (measured by DO) from algae decomposition.

Table 3. Top Indicators by Monitoring Category

Indicator Category	Top Indicator/Metric
Biodiversity	Fish communities (5)
Community Use and Engagement	Stewardship (3)
Environmental and Biological Health	Toxic contaminants (4 in fish tissue, 4 in sediments)
Human Development and Impact	Water use (5)
Key Species	Oysters (4)*
Land Use and Habitat	Wetlands (7)
Water Quality	Nutrients (21)
Weather and Climate	Wind (6)

*Oysters are the most common key species indicator across programs- the most common indicator over all is phytoplankton, measured ten times by the Lake Champlain Long-term Monitoring Project

Ten out of twelve programs monitor 34 indicators relating to this nutrient loading–algal bloom–DO relationship. However, this total does not include indicators that measure human activities that lead to nutrient loading, like wastewater treatment discharge or combined-sewer overflows. These indicators are key to understanding the human impact on the ecosystem and supporting management decisions.

While most programs did not directly tie these indicators to ecosystem services, Delaware Estuary Program and Piscataqua Region Estuaries Partnership note the importance of nutrient concentration and the negative effects of excess nutrients on water quality. America's Watershed Initiative is one of the few programs to identify specific ecosystem services that benefit from improved water quality.

Emerging Indicators

Some indicators in the inventory address areas of emerging concern such as climate change. We included stewardship and engagement in this group, since these efforts can be difficult to qualify but are increasingly important to ecosystem conservation and longevity.

Climate Change, Extreme Events, and Resiliency

Climate change can negatively affect ecosystem services and alter the makeup of the system itself. Climate change indicators are largely an extension of weather data as they take information on precipitation and temperature report and analyze it to identify changing trends in weather patterns and abnormal conditions. Most programs monitor climate change by tracking extremes or calculating changes over time. Other programs monitor weather data (e.g., precipitation, snow cover, and water temperature) without highlighting these climatic changes or irregular events. Moreover, most of the programs we interviewed identified these climate change-related indicators as an area of growing concern.

Table 4 shows the climate change-related indicators and associated metrics from the literature review, which include sea level rise and acidification in addition to weather related metrics. While Tampa Bay Estuary Program is the only program monitoring acidification as a climate change effect, a handful of others monitor changes in pH without attributing the cause to climate change.

Table 4. Climate Change Metrics		
Indicator	**Indicator Description (Metric)**	**Data Collected**
Climate resiliency *Chesapeake Bay Program*		Average air temperature increases. Change in high temperature extremes. Stream temperature change. Change in total annual precipitation. River flood frequency. River flood magnitude. Relative sea level rise.
Climate change *NY NJ Harbor and Estuary Program*	Emission of excess anthropogenic carbon dioxide and other greenhouse gases into the atmosphere increase average temperatures.	Average winter water temperature over time.
Climate characteristics *Tampa Bay Estuary Program*	Weather characteristics (temperature, precipitation, tropical storm or hurricane strength, etc.)	Annual rainfall. Average annual evapotranspiration. Number of extreme events.
Extremes: air temperature and precipitation *Delaware Estuary Program*	Occurrence of extreme temperatures, droughts, and heavy precipitation events.	number of consecutive dry days per year. Annual maximum five-day precipitation total. Days per year with heavy precipitation.
Sea Level *Narragansett Bay Estuary Program* *Tampa Bay Estuary Program*		Water levels and relative mean sea level trends.
Acidification *Tampa Bay Estuary Program*	Increased greenhouse gases in the atmosphere increase ocean acidification.	Change in pH level.

Stewardship and Engagement

While most community-focused indicators are centered around fishing, aquaculture, and recreation, we see some emerging trends in environmental engagement and stewardship (e.g., environmental literacy and citizen science). These programs all have a different approach to monitoring engagement, as detailed in Table 5. Programs that monitor these indicators identify their importance in continued environmental protection and restoration. Most of the programs in the inventory include a community or advocacy component in their long-term goals, and many have robust volunteer groups and partnerships as part of their environmental monitoring efforts. The volunteers and participants captured in these indicators are not only beneficiaries of the ecosystem services, but they are also important actors in preserving and promoting ecosystem services in their communities.

Table 5. Stewardship and Engagement Metrics		
Indicator and Program	**Indicator Description (Metric)**	**Data Collected**
Citizen science *NY NJ Harbor and Estuary Program*	Amount of research conducted by the public such as individuals, schools, nonprofits, and community-based organizations.	Number of citizen science organizations.
Civic engagement *NY NJ Harbor and Estuary Program*	Amount of public engagement in watershed advocacy.	Number and membership in stewardship programs. Staff and volunteers in stewardship programs. Participation in stewardship events.
Environmental literacy *Chesapeake Bay*	Number of students with the knowledge and skills needed to protect and restore their local watersheds.	Environmental literacy preparedness survey. Meaningful Watershed Educational Experiences (MWEE) available. Certified sustainable schools in the Chesapeake Bay Watershed.
Stewardship *Chesapeake Bay*	Size and amount of diverse community stewards for watershed restoration.	Citizen stewardship index. Personal stewardship, volunteerism, and civic engagement. Chesapeake Bay Program diversity profile. Local leadership engagement.
Stewardship *Piscataqua Region Estuaries Partnership*	Volunteer hours and signups for stewardship-related activities.	Volunteer hours by selected stewardship groups. Volunteer events and signups.
Stewardship *Puget Sound Partnership*		Engagement in stewardship activities survey, sound behavior index.

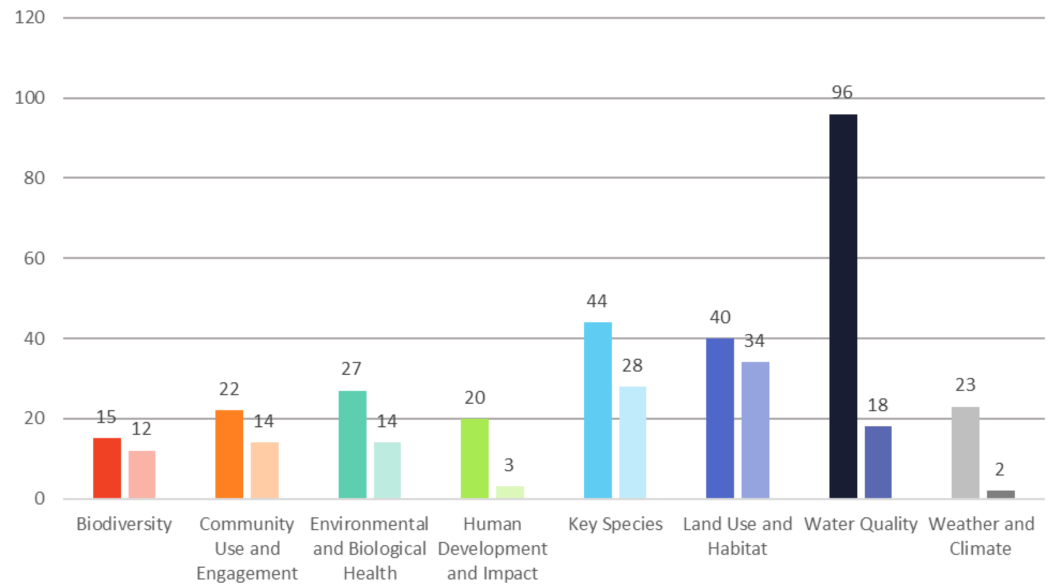
Gaps

Most of the programs in the inventory include improved water quality as part of their mission or long-term goals, along with improved stewardship, conservation, resiliency, and sustainable ecosystem management. However, few indicators monitor anthropogenic stressors that result in poor environmental outcomes.

Connecting Ecosystem Services and Indicators

Nearly half of the indicators in the inventory are connected to at least one ecosystem service by their monitoring programs. Figure 2 shows the total number of indicators connected to ecosystem services by monitoring category compared to the total number of indicators in that category. 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 trend coincides with our interview findings that many programs struggled to make the connection between water quality indicators (e.g., nitrogen) to tangible benefits or costs to the public. Additionally, the programs almost never identified the often-negative relationship between stressor indicators across categories (e.g., invasive species, impervious surface) and ecosystem services.

Figure 1. Ecosystem Services Identified in National Inventory by Category



For each category, the column on the left represents total indicators per category and the column on the right represents number of indicators connected to an ecosystem service.

4. Phase 2 Results

Phase 2 of the literature review focuses on the programs located directly in the SNEP region and those adjacent to it (see Figure 3). As with the national inventory, we analyzed the indicators to identify commonalities, emerging areas of concerns, and gaps. We used the additional information gathered in this phase to look at the connection between indicators and ecosystem services in more detail, consider the geographical distribution of program monitoring, and identify regional data sources.

The number of indicators by monitoring category for each program are displayed in Figure 4. Since each programs' monitoring goals varied, the breadth and quantity of indicators measured differed as well. Some programs had partnerships with other organizations, NGOs, academic institutions, and volunteer groups that reduced their need for monitoring. Most programs monitor land use and habitat, with an emphasis on wetlands. In this phase, we also interviewed six of the programs to solicit feedback on their monitoring program's goals, challenges, and future direction. The information gathered from the interviews is summarized in this section as well.

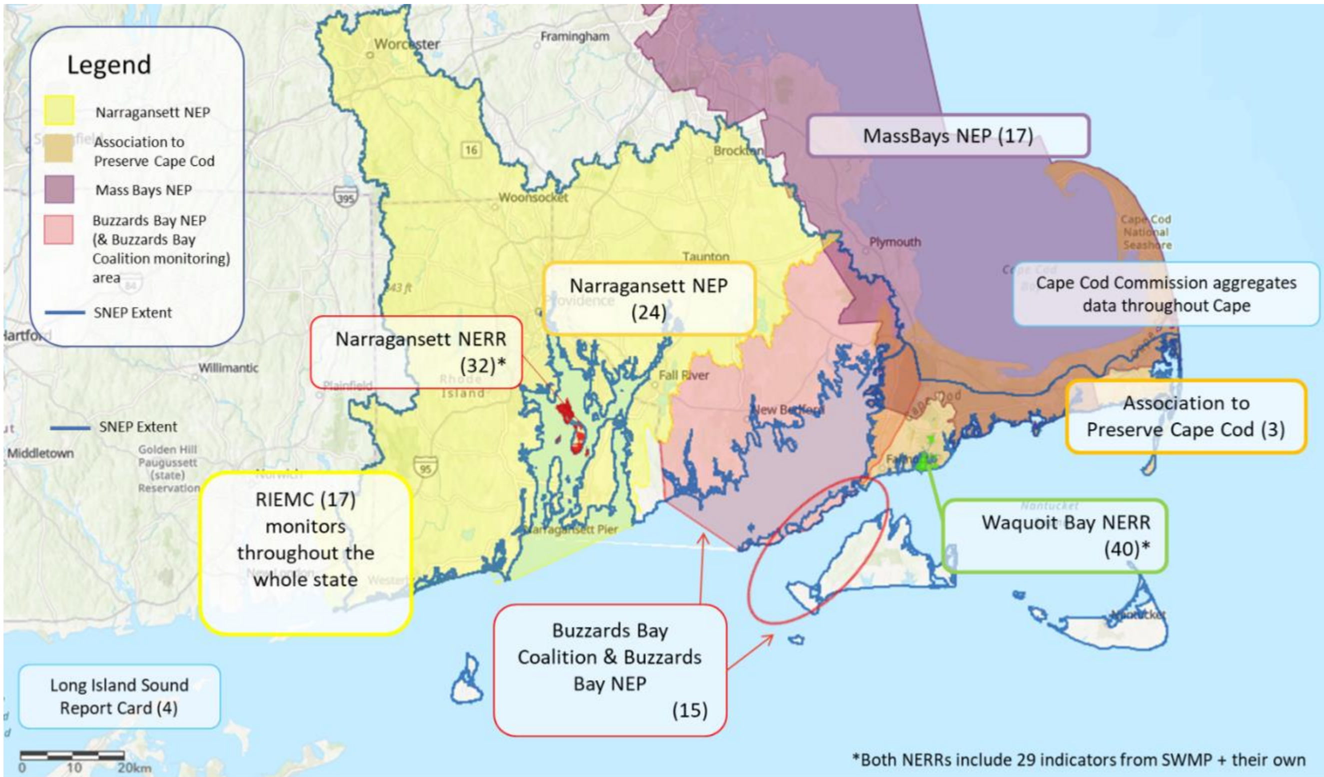
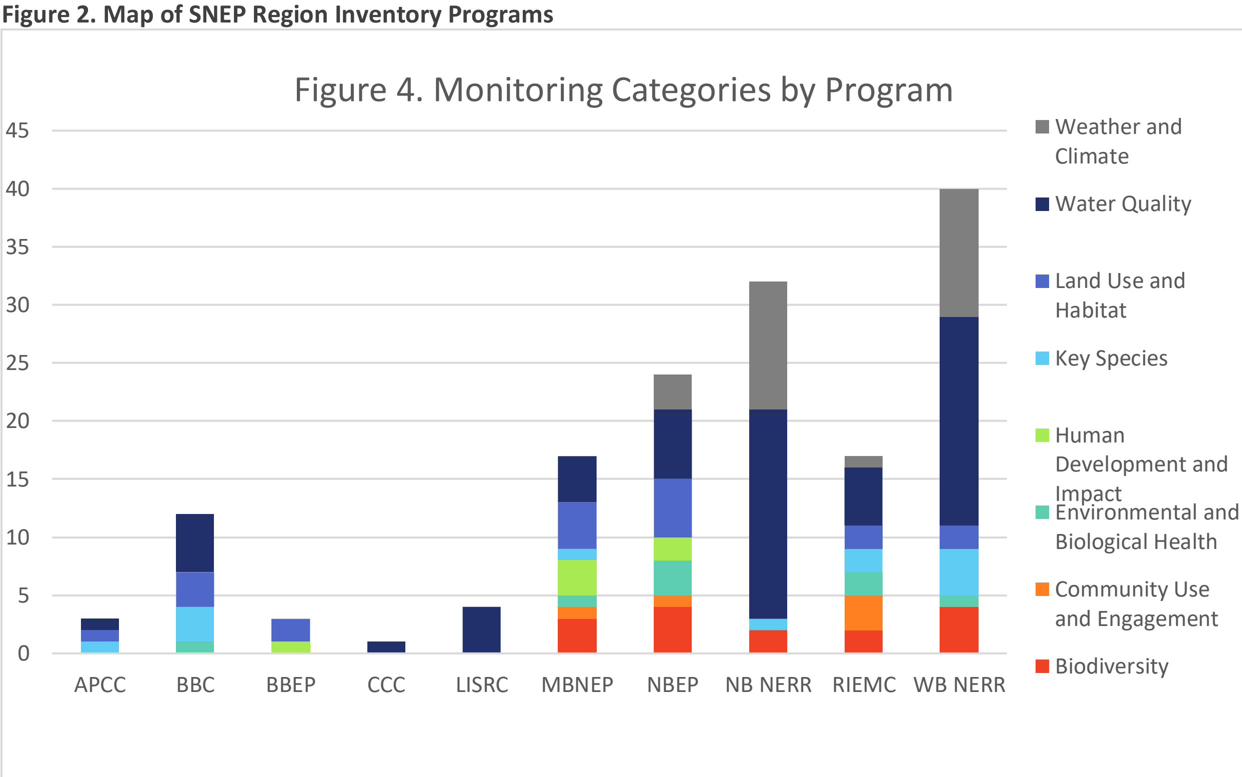


Figure 2. Map of SNEP Region Inventory Programs



Common Indicators

As demonstrated in Figure 3, water quality is the dominant monitoring theme in the SNEP region. Table 6 shows the top indicators measured per each category. The Cape Cod Commission (CCC) is in the process of aggregating much of the water quality data collected on Cape Cod (the Cape) into a central repository. Data sources for CCC include Buzzards Bay Coalition and Waquoit Bay NERR, which are both included in the inventory. The regional inventory has a similar distribution of indicators as the nationwide inventory, with about fifty percent of indicators covering some part of the nutrient loading–algal bloom–DO relationship. Nine out of ten programs have at least one indicator monitoring nitrogen, algal blooms, or DO. While Buzzards Bay NEP is the only one in the inventory without water quality indicators, they started the volunteer water quality monitoring program that the Buzzards Bay Coalition now operates on their behalf.

Table 6. Top Indicator by 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	Eel grass (3)
Land Use and Habitat	Wetlands (8)
Water Quality	Nutrients (14) [11 nitrogen, 3 phosphorous]
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.

Common Data Sources

Seven programs leverage existing data for some or all their indicators. Table 7 presents the data sources listed in the inventory more than once. Programs within the SNEP region collaborate and leverage each other's data as well. CCC does not collect any of their own data, instead collecting and standardizing data from other programs on the Cape. Their sources include Waquoit Bay NERR and Buzzards Bay Coalition.

For their State of the Waters project, the Association to Preserve Cape Cod (APCC) collected and analyzed existing water quality data throughout the Cape. Their sources included CCC, Buzzards Bay Coalition, and Waquoit Bay NERR. MassBays National Estuary Program is working on a similar aggregation for their study area, collecting the data from qualifying programs which include citizen science efforts, local and regional government monitoring, and non-profits.

Ecosystem Service Trends

Not every program explicitly connects ecosystem services to their indicators. In Phase 2, just over one-third of indicators were connected to ecosystem services. Only a handful identified beneficiaries or included valuations. Figure 5 presents the number of indicators per category that identified ecosystem services compared to the total indicators in each category.

While water quality indicators compose the bulk of most programs' monitoring efforts, they too are rarely connected to ecosystem services. Instead, most programs connected ecosystem services to biological and habitat indicators or human use. Indicators were almost always identified when a positive relationship existed between indicator and ecosystem service (i.e., when they supported or provided an ecosystem service). Indicators that negatively impacted the quality of ecosystem services are rarely identified as doing so.

Table 7. External Data Sources	
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 Mussel Watch (NOAA)	2
Provincetown Center for Coastal Studies	2
Rhode Island Geographic Information System (RIGIS)	2
United States Census Bureau (USCB)	2

We used the ISEF to classify the ecosystem service into categories (defined in Table 8 and displayed in Figure 6) and then listed the ISEF subcategories to as much detail as possible based on report description. Table 9 lists the most common indicators measured for each ecosystem service category. We found:

- 90 percent of programs had at least one indicator connected to an ecosystem service.
- 54 out of 153 indicators were connected to at least once ecosystem service.
- 19 indicators identified at least once beneficiary.
- Sixteen indicators were associated with ecosystem service valuations. Half of these were qualitative valuations and the other half quantitative.

Most biodiversity and key species indicators identify ecosystem services, while all the community use and engagement make at least one connection. Although water quality indicators make up half of all indicators, only a small percentage of them are connected to ecosystem services. Within water quality metrics associated with ecosystem services, indicators measuring bacteria and water clarity are the most common. Only Narragansett Bay NEP connected nitrogen to ecosystem services, despite nitrogen being the most popular indicator among both inventories.

Table 8. Ecosystem Service Category

Ecosystem Service Category	Definition[1]
Cultural	Nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience.
Provisioning	Products obtained from ecosystems, including genetic resources, food and fiber, and fresh water.
Regulating	Benefits obtained from the regulation of ecosystem processes, including regulation of climate, water, and some human diseases.
Supporting/Habitat	Ecosystem services necessary for the maintenance of all other ecosystem services. Examples include biomass production, production of atmospheric oxygen, and nutrient cycling.

Table 9. Common Indicators for ES Groups

Cultural	Fish communities/fish species (9)
Provisioning	Fish communities (6)
Regulating	Wetlands (8)
Supporting/ Habitat	Wetlands (8)

[1] Definitions for the ecosystem service categories obtained from http://www.teebweb.org/resources/glossary-of-terms/

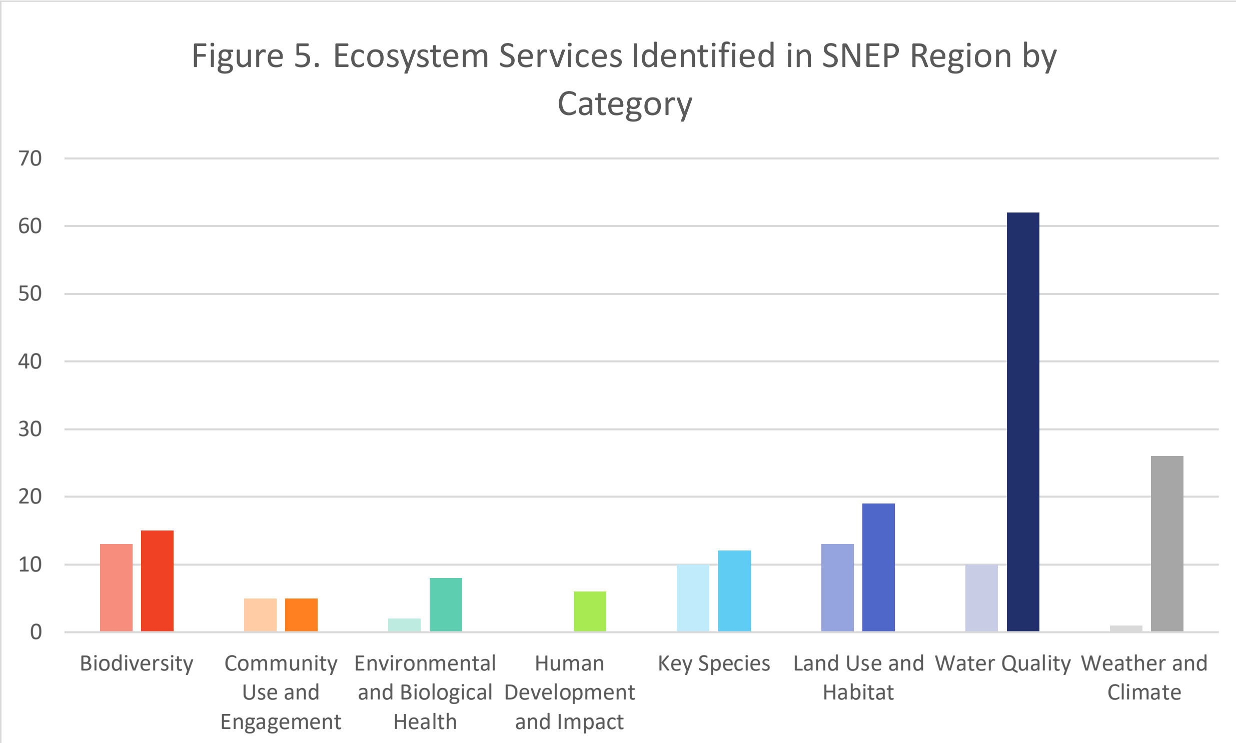
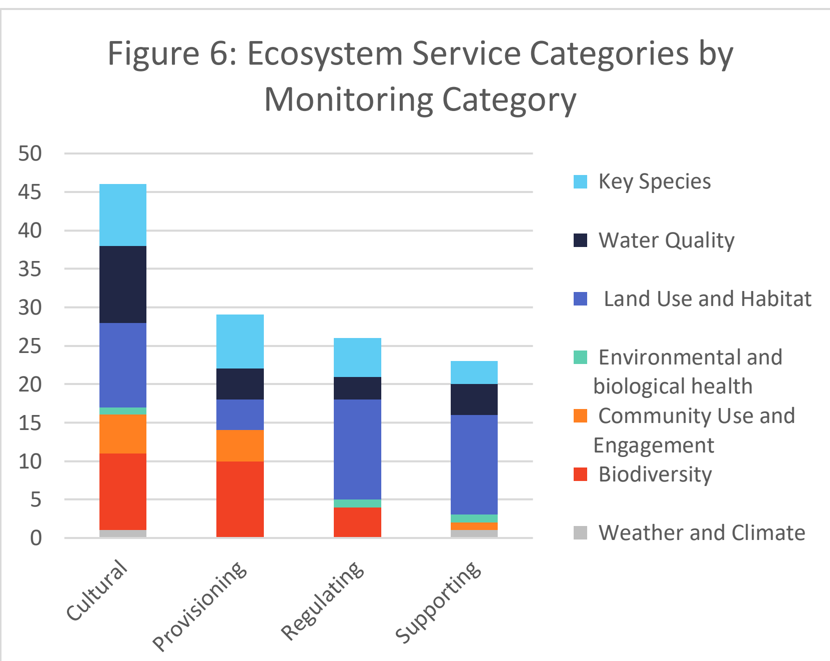


Figure 4: For each category, the column on the left represents number of indicators connected to an ecosystem service and the column on the right represents total indicators per category.



Cultural Services: From the 46 indicators that identify cultural ecosystem services, 19 of those indicators reference recreational fishing, while all of them reference recreation at some level. Most of the indicators linked to recreational fishing relate to wetland habitat or fauna. Ten indicators reference cultural heritage.

Provisioning Services: Of the 29 provision ecosystem services identified, 23 of them specifically refer to commercial fishing and food sources. Most of these indicators (15) monitor the status or abundance of aquatic organisms (either specific species or groups of species). Many of these indicators rely on existing datasets, often from the MassDMF and RIDEM.

Regulating Services: Of the 26 indicators connected to regulating ecosystem services, 16 reference coastal protection as a provided service. Most of these indicators measure areas, acreage, or extent of habitat or vegetation, highlighting the importance of habitat and land use indicators.

Supporting Services: Twenty-three indicators identify supporting ecosystem services. These indicators mostly measure the extent of key habitat for each program. Habitat protection and availability are associated with several ecosystem services- all supporting ecosystem service indicators identified regulating services, and seven identified cultural services as well.

Fisheries and Wetlands Monitoring

Wetlands and fisheries were the two most common indicators in the SNEP region (see Table 9). Wetlands and fisheries are key issues for the SNEP region, providing services across all four ecosystem groupings and serving many beneficiaries. While indicators like nitrogen concentration and DO are important for management and conservation efforts, fish population and wetlands are more easily recognizable indicators that the public can relate to and understand.

Each program framed and approached wetland monitoring differently. Some programs looked specifically for the change in wetlands over time, while others focused on current condition and health. Commonly used parameters within wetland monitoring are extent, elevation, flora, and fauna. Wetlands are crucial to many ecosystem services, and monitoring multiple components creates a better understanding of their ability to provide these services.

Moreover, commercial and recreational fishermen were the most frequently identified beneficiaries, which aligns with fisheries being most identified ecosystem service. Fishing population data is most frequently taken from the MassDMF and RIDEM. While some programs have focused on key species in their area, like APCC, others reported on many species. Tables 10 and 11 contain the various ways SNEP programs monitor wetlands and fisheries, respectively.

Table 10. Data Collected for Wetland Indicators

Program	Indicator	Indicator Description (Metric)	Data Collected	Data Type	Data Source
Association to Preserve Cape Cod	Wetlands (freshwater)	Status of salt marsh		Direct measurements	N/A
Buzzards Bay Coalition	Wetlands (estuarine/ marine)	Extent and health of wetlands	Elevation, vegetation, and fauna.	Direct measurements	N/A
Buzzards Bay Estuary Program	Wetlands (estuarine/ marine)	The potential expansion and migration of existing salt marshes, particularly those that are in tidally restricted areas	Evaluating the salt marsh expansion and migration with 1-foot, 2 feet and 4 feet increases in sea level.	Existing data sets	Atlas of Tidally Restricted Marshes in Buzzards Bay Watershed
MassBays National Estuary Program	Wetlands (estuarine/ marine)	Extent and restoration of tidal wetlands	Completed restoration projects. Field monitoring.	Existing data sets	MassCZM, MassDER
Narragansett Bay Estuary Program	Wetlands (estuarine/ marine)	Area of intertidal ecosystems between land and open saltwater or brackish water along protected shorelines and embayments	Salt marsh acreage over time.	Existing data sets	USFWS National Wetlands Inventory
Rhode Island Environmental Monitoring Collaborative	Wetlands (estuarine/ marine)	Salt marsh extent, vegetation and migration	Landscape scale aerial data, field assessments, researched-based in-depth studies of flora and fauna at certain sites.	Existing data sets	Narragansett Bay NERR, Save the Bay, RI CRMC, RI NHS
	Wetlands (freshwater)	Maps and evaluates wetland health	Landscape scale aerial data, field assessments, researched-based in-depth studies of flora and fauna at certain sites.	Existing data sets	RIDEM, RI NHS
Waquoit Bay NERR	Wetlands (estuarine/ marine)	Extent of salt marsh		Direct measurements	N/A

Key: RI CRMC Rhode Island Coastal Resources Management Council; RI NHS Rhode Island Natural History Survey; USFWS United States Fish and Wildlife Service; MassDER Massachusetts Division of Ecological Restoration

Table 11. Data Collected for Fisheries Indicators				
Program	**Indicator**	**Data Collected**	**Data Type**	**Data Source**
Association to Preserve Cape Cod	River herring	Population estimates, adult river herring counts.	Direct measurements	N/A
Buzzards Bay Coalition	Bay scallops	Bay scallop catch (bushels).	Existing data sets	Mass DMF
	River herring	River herring counts.	Direct measurements (Baywatchers program)	N/A
MassBays National Estuary Program	Fish communities	Biannual bottom trawl surveys.	Existing data sets	Mass DMF
	Fish communities	Census counts and catch per unit effort of River herring, American Shad, Rainbow Smelt, and American Eel.	Existing data sets	Mass DMF
Narragansett Bay Estuary Program	Fish communities (estuarine)	Ratio of pelagic to demersal species. Abundance of species that prefer warm or cold water.	Existing data sets	GSO, RIDEM
	Fish communities (freshwater)	Fish sampling data. Brook trout habitat extent.	Existing data sets	RIDEM DMF, MA DFW
RIEMC	Coastal fisheries	Trawl surveys for relative abundance of finfish and shellfish assemblages.	Existing data sets	RIDEM
	Lobster Population	Trawl and ventless lobster trap survey, Commercial Harvester Catch and Effort Logbook.	Existing data sets	RIDEM
Waquoit Bay NERR	Fish communities	Annual seine survey.	Existing data sets	Now by Mass DMF
	Trout	Movement of tagged fish. Size of ranges. Migration patterns. Habitat usage. Population characteristics.	Direct measurements	Now by Mass DMF
RIEMC Rhode Island Environmental Monitoring Collaborative ; MassDMF Massachusetts Division of Marine Fisheries; RIDEM Rhode Island Department of Environmental Management; MassDFW Massachusetts Division of Fisheries and Wildlife, GSO URI's Graduate School of Oceanography				

Gaps

We also analyzed the expanded inventory of SNEP region programs to look for gaps in indicators and metrics, ecosystem services and geographic coverage. We identified gaps by comparing the distribution of monitoring categories and ecosystem services across programs and between the national database. Within each theme, indicators were compared for diversity. We found gaps in the following areas.

Indicators and Metrics

- **Biodiversity and Key Species:** Multiple interviewees commented on the lack of biological monitoring within their region and cited anecdotal evidence of die-offs that monitoring missed. The SNEP region inventory contains a smaller percentage of key species indicators compared to the national data and reports heavily on fish populations, neglecting other aquatic and terrestrial life.

- **Community Use and Engagement:** Community use indicators within the SNEP region primarily monitor the population's relationships to shellfish harvesting, which only MassBays National Estuary Program, Narragansett Bay Estuary Program, and Rhode Island Environmental Monitoring Collaborative monitor. The indicators in the national inventory are more diverse and include volunteers, citizen science efforts, and environmental literacy. These are emerging indicators that help demonstrate outreach efforts and encourage stewardship. Considering most program goals have a public engagement or outreach component, indicators relating to that effort are lacking.
- **Environmental and Biological Health:** Monitoring for toxic contaminants and pollution are crucial for ecosystem services like fishing. There are only five indicators among four programs monitoring for toxic pollutants or contaminants (e.g., trace metals, mercury, polychlorinated biphenyls, etc.) which have direct, negative impacts on fisheries. More data on contaminants, especially emerging ones which have the potential to harm those who eat seafood, would benefit both ecosystem and public health.
- **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. However, other programs from Phase 1 include a wider range of human disturbances 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.
- **Sea Level and Climate Change:** Weather and climate change data is lacking in most of the SNEP region. The Narragansett Bay Estuary Program includes the most climate change indicators into monitoring efforts: they are the only program in the SNEP inventory monitoring sea level rise. In their report, they note the lack of data available in the Bay, and the "considerable uncertainty in predicting response to acidification in the estuarine environment"[2]. Multiple interviewees brought up the need for more climate change and weather indicators as well.

Ecosystem Services

- **Identifying Beneficiaries:** Commercial and recreational fishermen are the most often identified beneficiaries. While they are key to the region economically, there are many other beneficiaries in the IESF that could be connected to the currently monitored indicators. By drawing the connection to additional beneficiaries, monitoring programs could engage a wide group of stakeholders. Beachgoers, homeowners, outdoor enthusiasts, and governments are each identified a handful of times as beneficiaries within the SNEP region.
- **Connecting to Ecosystem Services:** Ecosystem services are affected by human and environmental factors, particularly with habitat and species. Few indicators make that link with water quality, human developments and impacts, and weather and climate metrics. Indicators that have negative impacts on ecosystems are rarely explicitly connected to goods and services, though they can impact the quality and value of ecosystem goods and services significantly.

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[2] http://nbep.org/01/wp-content/uploads/2017/03/State-of-Narragansett-Bay-and-Its-Watershed-lower-resolution.pdf

- **Valuations:** Few indicators were connected to a quantitative or qualitative valuation. Those that were valued were most often an indicator of cultural or provisioning ecosystem services. Supporting and regulating ecosystem services were rarely valued.

Geographic Scope

- **The Islands:** The SNEP region includes the islands of Martha's Vineyard and Nantucket, but they are underrepresented in the inventory. Buzzards Bay Coalition is the only program working within Vineyard Sound, and its reach does not encompass the entire island.
- **Weather data** is collected mostly in Narragansett Bay, with some indicators monitored in the Waquoit Bay NERR, although that covers a very small geographic area. Weather and climate indicators are a crucial environmental factor affecting ecosystem services and health. With the threat of climate change, collecting weather data is even more crucial to understanding impacts on ecosystems.

Funding

- Lack of continuous funding has created temporal gaps within programs' regular monitoring intervals. These gaps became particularly apparent during our interviews, but some programs also noted such gaps in their reports and on their websites, including the Narragansett Bay Estuary Program and Rhode Island Environmental Monitoring Collaborative.
- Many programs rely on grants and have robust volunteer programs to help alleviate costs. Some programs have even stopped their own data collection, instead relying on other groups collecting the same or similar data. Struggles to secure long term funding also prevent program expansion.

SNEP Region Monitoring Program Outreach

In addition to interviewing programs to fill in any data gaps, we asked each program a series of questions recommended by the Subcommittees. The answers to these questions are summarized below:

Communicating to the Public: Most programs found people in the area did not necessarily understand the connection between certain indicators and their daily lives. For example, learning the nitrogen concentration in the water does not immediately give the average user an idea of water quality conditions. Many programs are working on drawing the connections between measurements and indicators to management and local action.

Key Indicators: All the programs we interviewed are doing a lot of work with DO, chlorophyll, and nitrogen. However, these indicators are primarily used for management projects and not public outreach efforts. Indicators used to leverage public action are more likely to be related to key species (i.e. River herring) or shellfish closures. It was also noted that weather indicators resonated with the public.

Data and Research Needs: Many programs identified a need for monitoring biological conditions in aquatic environments. Anecdotal evidence tells us benthic environments are changing (e.g., the recent lobster die-off on the Cape and the Waquoit Bay fish die-off). Programs agreed that this information is not captured in the current monitoring data and expressed interested in expanding monitoring to include more data on aquatic organisms and biological activity.

Program Goals: Monitoring programs are looking to expand their goals to include acidification data, stormwater data, and more detailed saltmarsh monitoring.

Funding: Lack of consistent funding was a key point brought up in all our interviews. Some programs rely on volunteers to monitor key indicators to keep costs down. Many programs use grants to partially fund some of their monitoring; however, this jeopardizes and could potentially prevent long term data collection and planning. The reliance on grants can create inconsistencies in monitoring, which is particularly is important for restoration projects as some habitats take years to show results.

SNEP's Role in Regional Monitoring Efforts: Throughout our interviews, most programs identified two major priorities for SNEP: supporting continued funding for monitoring and bringing together data from all the monitoring in the region. Some programs recommended prioritizing projects that address the environmental issues revealed by current monitoring efforts. For example, the data show nitrogen and eutrophication issues throughout the region. Interviewees want to see funding for projects addressing the causes of eutrophication along with monitoring nitrogen loading. Others expressed interest in funding to increase stormwater, sea level rise, and ocean acidification monitoring efforts. Nearly all interviewees also stressed the difficulty in obtaining enough funding to consistently run their current programs.

Many programs suggested that SNEP work to bring monitoring program data together to tell a cohesive story of environmental issues in the region. Most of the programs we interviewed do not have the capacity to take a broad view of all the data coming out, identify gaps, or demonstrate the value of the current monitoring to the general public. They suggested SNEP could bring the region's monitoring data together and translate it into a form that is accessible for the public.

5. Conclusions and Recommendations

Using the findings reported in the last section, we present our recommendations on how to use the inventory with the IESF, our recommendations for SNEP indicator priorities, and suggest future applications of this work.

Overall, the distribution among monitoring categories was similar for the national and SNEP region programs, with both containing a heavy emphasis on water quality. Neither the U.S. nor the SNEP region programs connected many of their indicators to ecosystem services. SNEP region programs had a significantly higher proportion of biodiversity indicators compared to national programs.

Within the monitoring categories, the indicators from SNEP region programs have less diversity than those of the national programs. The geographic range of the national inventory explains some of variety, as each region has different focuses and community concerns. However, some indicator categories would provide a more comprehensive picture of the SNEP region if expanded–namely weather and climate and community use and engagement indicator groups.

Ecosystem Services: Most of the indicators in the inventory are related (positively or negatively) to one or more ecosystem services, yet few are explicitly connected. Even fewer highlight the beneficiaries of identified ecosystems or valuations. There is an opportunity to draw these connections to improve communication and translation of indicators to the public.

Biodiversity and Key Species: There is a need for more comprehensive and frequent biological monitoring. Our interviews found programs were not capturing major events, such as lobster die-offs, in their data. Additionally, programs have found the public responds well to indicators of key species, like River herring. These indicators are easily understood, while also revealing key information for aquaculture and fisheries.

Community Use and Engagement: Reporting on this category could be expanded. Its indicators are not diverse or as frequent among programs in the SNEP region, compared to the national inventory. SNEP region reporting focuses on shellfish and aquaculture, ignoring other uses and users. Potentially useful indicators include volunteer hours, citizen science efforts, and beach use.

Environmental and Biological Health: This category is covered throughout the region through monitoring a variety of contaminants, with most indicators analyzing a variety of contaminants in mussel tissue.

Human Development and Impact: Reporting on this category could be expanded. Most programs have few human development and impact indicators, and those that include them fail to connect them to ecosystem services, despite their influence on ecosystem health and function.

Land Use and Habitat: This category is well represented and reported on throughout SNEP, primarily reporting on natural spaces.

Water Quality is a top priority and well monitored throughout the SNEP region. Key indicators for water quality are nitrogen, dissolved oxygen, chlorophyll, bacteria and harmful algal blooms. The CCC is currently putting together a data aggregator that SNEP could leverage for water quality reporting. Massachusetts Water Resources Authority, CCC, the Center for Coastal Studies, and RIDEM are all potential water quality data sources.

The IESF could be used to connect ecosystem services and beneficiaries to water quality metrics, particularly for the most popularly used indicators: nitrogen and DO. These indicators can demonstrate both human impacts on water quality (e.g., high nitrogen levels could indicate combined sewer overflow or wastewater treatment effluent) and the effects on humans (e.g., closed shellfish beds due to resulting harmful algal bloom) because of the water conditions.

Weather and Climate: Reporting on this category could be expanded, particularly for climate change-related indicators. Weather data is only reported by one program outside of the Narragansett watershed and climate change indicators are rarely reported, but there is growing interest in understanding climate impacts. Multiple programs that we interviewed mentioned the importance of change climate data because of its effects and its metrics are more tangible to the public (i.e., precipitation events). Temperature, precipitation, and other weather data are heavily monitored by federal agencies (e.g., USGS, NOAA) that could be pulled and synthesized for public access and understanding and cover the entire region.

Leveraging Existing Sources: There are many opportunities to leverage data currently being collected. The Cape Cod Commission is a prime example of a program leveraging multiple efforts and creating a central database that SNEP could leverage. CCC uses information from local monitoring programs including inventory programs Buzzards Bay Coalition and Waquoit Bay NERR.

Massachusetts and Rhode Island state data were used often throughout the SNEP inventory. Common sources include Massachusetts Department of Environmental Protection, Rhode Island Department of Environmental Management, Massachusetts Division of Marine Fisheries, Massachusetts Division of Fisheries and Wildlife and Rhode Island Department of Health. Commonly used national datasets come from NOAA and USGS.

Recommendations

With respect to the use and development of the database, we recommend the following:

1. Revise the indicator categories as management questions develop and change. Categories allow the database to be easily searched to address key questions about monitoring the region. Updated categories compatible with SNEP management questions and goals will make for easier use of the inventory.

2. Update the IESF to include the indicator categories from the inventory. These 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.
3. Use the IESF to explicitly connect indicators and metrics to beneficiaries and services in reporting. When possible, select a diverse range to demonstrate benefits apply widely. Currently, the programs in the inventory mostly identify commercial and recreational fishing. While fisheries are crucial cultural and economic drivers in the region, there are many additional services and beneficiaries that could be identified.

Deploying the IESF as a framework to connect indicator data to ecosystem services, address management questions, and communicate environmental information to the public could highly benefit SNEP and all the monitoring programs in the region.

SNEP Indicators and Metrics Literature Review Guide

Context

This literature review identifies existing monitoring programs across the United States and highlights key information and commonalities from their reports that supported the created of the Integrated Ecosystem Services Framework (IESF) for the SNEP region. The review was divided into two phases, resulting in the "All Indicators" tab and "Expanded indicators" tab. Phase 1 began with a broad geographic scope of programs throughout the US. Phase 2 took ten programs within and around the SNEP region and expanded the review to included additional information for these programs. The "All Indicators" tab includes indicators from Phase 1 and 2, but can easily filter out programs included in the "Expanded" tab using column J.

How to Read this Product

This sheet is broken out into five tabs: Programs, All Indicators Expanded Indicators, Pivot Tables for all indicators, and Pivot Tables for Expanded Indicators. We recommend starting with the Programs tab, which provides a high-level overview of all programs included in the research and includes links to the original data sources.

Next, we suggest looking at the Indicators-Metrics tab, which provides an in-depth look into each of the programs identified in the Programs tab. Each row should be read left to right. To make this sheet easier to read:

The initial four columns (Program, Monitoring Goal/Category, Indicator Group and Indicator) are frozen, which allows you to scroll across columns without forgetting which indicator you are looking at.

We organized the indicators in broader themes categorization to make filtering and analyzing the indicators easier. Each indicator was sorted into one of eight themes, using the definitions below:

- **Biodiversity-** Indicators assessing broader ecosystem health by monitoring multiple species or threats to biodiversity
- **Community Use and Engagement**- Indicators assessing human population and interactions with the ecosystem(s)
- **Environmental and Biological Health**- Indicators assessing non-water environmental quality and species health (e.g., bioaccumulation in fish, toxins in sediment)
- **Human Development and Impacts**- Indicators monitoring the built environment and human pollution (e.g., Combined sewer overflows, water use)
- **Key Species**- Indicators relating to a specific species which is integral to ecosystem services or health
- **Land use and habitat**- Indicators measuring land use, cover, or habitat area
- **Water quality**- Indicators measuring physical, chemical or biological contents in the water
- **Weather and Climate**- Indicators measuring meteorological and climate conditions, including climate change impacts

We have added filters to each of the column's headers. This enables you to select which data you want to view at a time. You could filter by program (e.g., view all information on the Puget Sound Partnership or the Chesapeake Bay Program) by indicator (e.g., view all information on Chlorophyll a or oysters) or by indicator category (e.g., Water Quality or Biodiversity).

Notes

While we were able to identify commonalities among the reports and pull out the information relevant to this project, all these programs are unique, and there is no "one size fits all" approach to monitoring ecosystem health. A few things to keep in mind during your review are listed below.

- To maintain the integrity of each report, we included information in the manner that the report presented it. For this reason, cells in columns F, G, and H in the Indicators-Metrics tab (and F-Q in the Expanded Indicators tab) may be left blank.
- Some programs did not fit as neatly into the categories as others. For example, the National Estuarine Research Reserve System and the Lake Champlain Long-term Monitoring Project focus on directly measuring quantitative data, while most other programs use qualitative and quantitative data to identify long-term trends and explain the benefits that each indicator provides to the ecosystem and to people. Thus, cells marked "N/A" indicate that the program or report did not include this information.
- Maryland DNR's Accounting for Maryland's Ecosystem Services report is also structured differently, as it does not use indicators to measure ecosystem health but rather conducts valuations for important ecosystem services.
- While many indicators can be connected to many ecosystem services and beneficiaries, we only included the ecosystem services and beneficiaries mentioned by programs.

The following table provide descriptions of each column in the first three tabs.

Table 2. Definitions of Columns in the Inventory

All Programs	All Indicators (Phase 1)	Expanded Indicators (Phase 2)
A. Program Name: Name of the monitoring program.	**A. Program:** Name of the monitoring program (from the Programs tab).	**A-H.** Same as in Tab 2
B. Geographic Region: Name of the watershed and the states the program covers.	**B. Monitoring goal/category: How** the program groups and categorizes its indicators.	**I-L. IESF Categories:** If the indicator was connected to any cultural, provisioning, regulating or supporting/habitat ecosystem services.
C. Bistate/Multistate: If the program covers more than one state	**C. Monitoring theme:** How our team classified each indicator into monitoring themes	**M. Total IESF Categories:** The number of ecosystems service categories covered by the identified ecosystem services.

E. Website Reference: Link(s) to data sources (reports, interactive web pages, etc.).	**E. Indicator description:** What the indicator measures (i.e., abundance of blue crabs, extent of forest cover, etc.). In some instances, this column provides additional context or description for the indicator.	**R. Beneficiaries Identified:** Beneficiaries specifically noted by the program, using ISEF terminology.
F. Contact Name: Contact listed for the report.	**F. Ecosystem function:** (where applicable) What role(s) the indicator plays within the ecosystem.	**S. Valuation Information:** Does the program conduct a qualitative valuation, a quantitative valuation, or no valuation?
G. Contact Email: Contact email.	**G. Ecosystem service:** (where applicable) What ecosystem service(s) the indicator provides.	**T. Data collected:** The data the program used to measure each indicator.
	H. Anthropogenic impact: (where applicable) For human-centric indicators (e.g., impervious cover, nutrient loading), this column describes the impact the indicator has on the ecosystem.	**U. Data type:** Does the program
I. Program Product Frequency: How often the program product is produced.	**I. Data collected:** The data the program used to measure each indicator.	**V. Data Source:** If the program uses existing datasets, this column lists the sources (likely state or federal agencies, universities, or nonprofits).
J. Indicators Measured: The number of indicators the program uses.	**J. Region:** If the program fell into the SNEP region (and therefore included in Expanded Indicators tab) or it was outside SNEP.	**W. Sampling Interval:** If the program conducts its own sampling, how frequently does it do so?
K. Measure of Progress: How the program measures progress. Not all programs include measures of progress (those cells are marked N/A).		

L. Program Mission/Long-term Goals:		
M. Program Budget: Estimate of monitoring program budget		

Pivot Tables and Charts Tabs

There is a pivot table tab for each indicator tab. Each tab contains two tables linked to charts. Both pivot table tabs contain one table displaying indicators per program by indicator category. The “All indicators” chart contains a filter for region to easily toggle between outside the SNEP region, inside the region or to show all indicators.

To change what information is displayed in a pivot table, go to the Analyze tab, and click “Field List”. From there change the filters, legend, columns, and rows. As the pivot table changes, the charts will update automatically. To change the chart type, go to the Design tab and click “Change Chart Type”. Useful filters include “Monitoring Category”, “Ecosystem Service” and the various ecosystem service categories.

To create a new pivot table, go to the Insert tab, click on “PivotTable”. When prompted for data source either type in “Table1” for the Expanded Indicators tab, or “Table3” for the All Indicators tab. Another option is to click on the tab you want and select the desired data range by hand.

Updating and Changing Monitoring Categories

As management questions develop it might make sense to change or reorganize the monitoring categories. That is easily done by going into the spread sheet and changing the text in column C. If changes are made for programs included in the SNEP region, they will also need to be updated in the All Indicators tab. If any changes are made to the inventory tabs, select the relevant table and click on “Refresh” in the Analyze tab, or right click on table directly and select refresh. Tables need to be updated individually.

Task 2.B. Report presenting a conceptual IESF including a functional schematic

Introduction

Complex coastal and transitional ecosystems, like the SNEP region, face many pressures including climate change, coastal erosion, overfishing, land use/land cover changes, and pollution. To build public support for the investment in restoration or other interventions and management actions meant to address these pressures, it is important to communicate the tradeoffs associated with all options. An Integrated Ecosystem Services Framework (IESF) will help SNEP quantify and communicate the numerous benefits that the ecosystem provides to communities. An IESF that links ecological conditions and/or functions to ecosystem services in the form of benefit-relevant indicators will provide insight into the potential impacts (positive and negative) associated with changes to the ecological conditions/functions (Olander et al. 2018). Since the IESF will highlight focal ecological conditions and functions, it can also be used to prioritize monitoring efforts for those focal conditions/functions. The goal of **Task 2.B.** was to develop a functional schematic of a SNEP region Integrated Ecosystem Services Framework (IESF) that represents 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.

This report is intended to describe the three stages of the conceptual IESF development to-date:

1. Brainstorm of IESF structural components including key functions and potential uses by the SNEP Ecosystem Services Subcommittee in December 2019;
2. Solicitation 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;
3. Development of a functional IESF schematic that captures the hierarchical nature of each component and conveys its interconnectivity.

In section 4, this report provides examples of how the IESF visualization is intended to be navigated and interpreted by different users and the issues they care about. Finally, in section 5, this report reflects on lessons learned from developing the SNEP IESF and makes recommendations for potential future work to further develop the IESF beyond the conceptual level required for this task.

1. IESF Structural Components

We first sought feedback on the overall IESF concept at a meeting of the SNEP Ecosystem Services Subcommittee on December 6, 2019 in New Bedford, MA. We started the discussion about what a SNEP IESF could look like by providing a very simple example flow chart (Figure 1), and other more complex examples (not shown here).

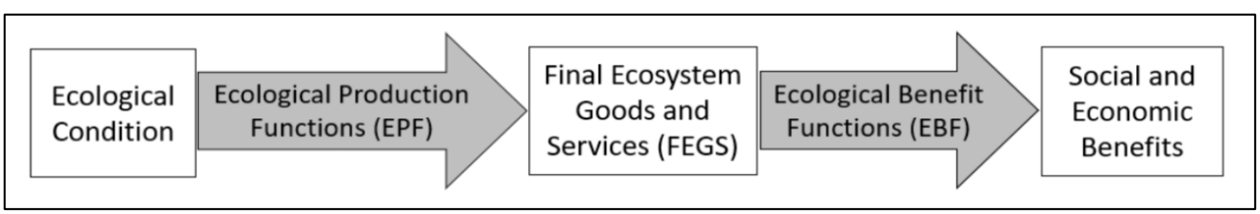


Figure 1. A simple example of an ecosystem services framework that links ecological condition to ecosystem services and the social and economic benefits provided to people (Yee et al. in review).

Participants provided detailed feedback via two different discussion groups. One group discussed the components (ecosystem goods and services, beneficiaries, indicators and metrics) that should be included in a SNEP IESF, and the other focused on the broader potential structure and function of an IESF. Subcommittee members were asked to talk about how the proposed project outputs could best address their needs; some possible uses of the project outputs; if there are other individuals who should inform/contribute to this effort; and if there are existing programs that we could learn from.

Subcommittee members generally agreed that the SNEP IESF should focus on estuarine and coastal ecosystem services in the near-term with the possibility of expanding to other watershed/terrestrial services in the future and should focus on water quality, habitat, and resilience elements. Although some Subcommittee members felt strongly that identifying potential IESF users would help drive the development of the framework, others felt that the IESF should be usable by a range of audiences from experts/decision-makers and technical contributors to the general public. For this reason, Subcommittee members requested that the IESF be constructed in a hierarchical and flexible way so that the most detailed information could be accessible by interested users, but also summarized and binned into upper levels of the hierarchy for more general audiences. Similarly, the Subcommittees discussed how the IESF structure should allow users to enter from any point of interest – ecosystem service, indicator, or beneficiary.

Overall, the picture that emerged from the December discussions was of a complex but expandable/collapsible network of ecosystem services, indicators, and beneficiaries with clear and simple terminology suitable for broad audiences.

Using the recommendations from the December meeting, we developed a preliminary database structure and visualization for the IESF (Figure 2A). The multivariate relational database was assembled in Microsoft Excel. The database captured the relationships between the three main IESF components: **Ecosystem Goods and Services**, **Beneficiaries**, and **Indicators and Metrics**. Relationships between and among components in the database were used as inputs for generating a network diagram in the R programming language. Using R to generate the IESF visualization makes future edits and revisions to the IESF database significantly easier to visualize than if the IESF network had to be regenerated manually each time.

To create a draft IESF visualization, we populated the database with Final Ecosystems Goods and Services (FEGS) and Beneficiaries from the EPA FEGS Query Tool (Landers and Nahlik, 2013) from the "near coastal marine and estuarine" environment category. Some example FEGS included "fauna", "flora", and "open space" and example **Beneficiaries** "food pickers and gatherers", "transporters of people", and "industrial processors". We roughly matched these components to **Indicators and Metrics** from the Narragansett Bay Estuary Program State of Narragansett Bay and Its Watershed report (Narragansett Bay Estuary Program, 2017). The preliminary IESF visualization (Figure 2A) was purely for testing and demonstration purposes to show how components of the IESF could be organized and presented schematically. These figures demonstrate the connections between the different components; in these example figures, all connections originate from the **Ecosystem Goods and Services**. In other words, **Ecosystem Goods and Services** are the central components of the IESF. For each **Ecosystem Good and Service**, there are **Indicators and Metrics** that can reflect the status, quantity, or delivery of that service, and there are **Beneficiaries** who are people receiving benefits from those services. When all relationships are viewed on the same schematic (e.g., Figure 2A), it can be difficult to trace all of the IESF connections. To make viewing easier for the user, the IESF can be "entered" from different areas of the schematic based on the user's needs and interests. These different entry points are illustrated in Figures 2B-D which highlight only the connections pertinent to each point of entry. For example, in Figure 2B, the **Beneficiary** group *Experiencers and Users* is the entry point, and the lines connect to relevant **Ecosystem Goods and Services** that this group benefits from, as well as the array of indicators that could be used to measure each **Ecosystem Good and Service**. An entry point for **Indicators and Metrics** is shown in Figure 2C (*Sea Level*; lines connecting relevant **Ecosystem Goods and Services** captured by *Sea Level* and their **Beneficiaries**) and an entry point for **Ecosystem Goods and Services** is shown in Figure 2D (*Water*; lines connecting to relevant **Beneficiaries** of *Water* and **Indicators and Metrics** for water quality, quantity, etc.).

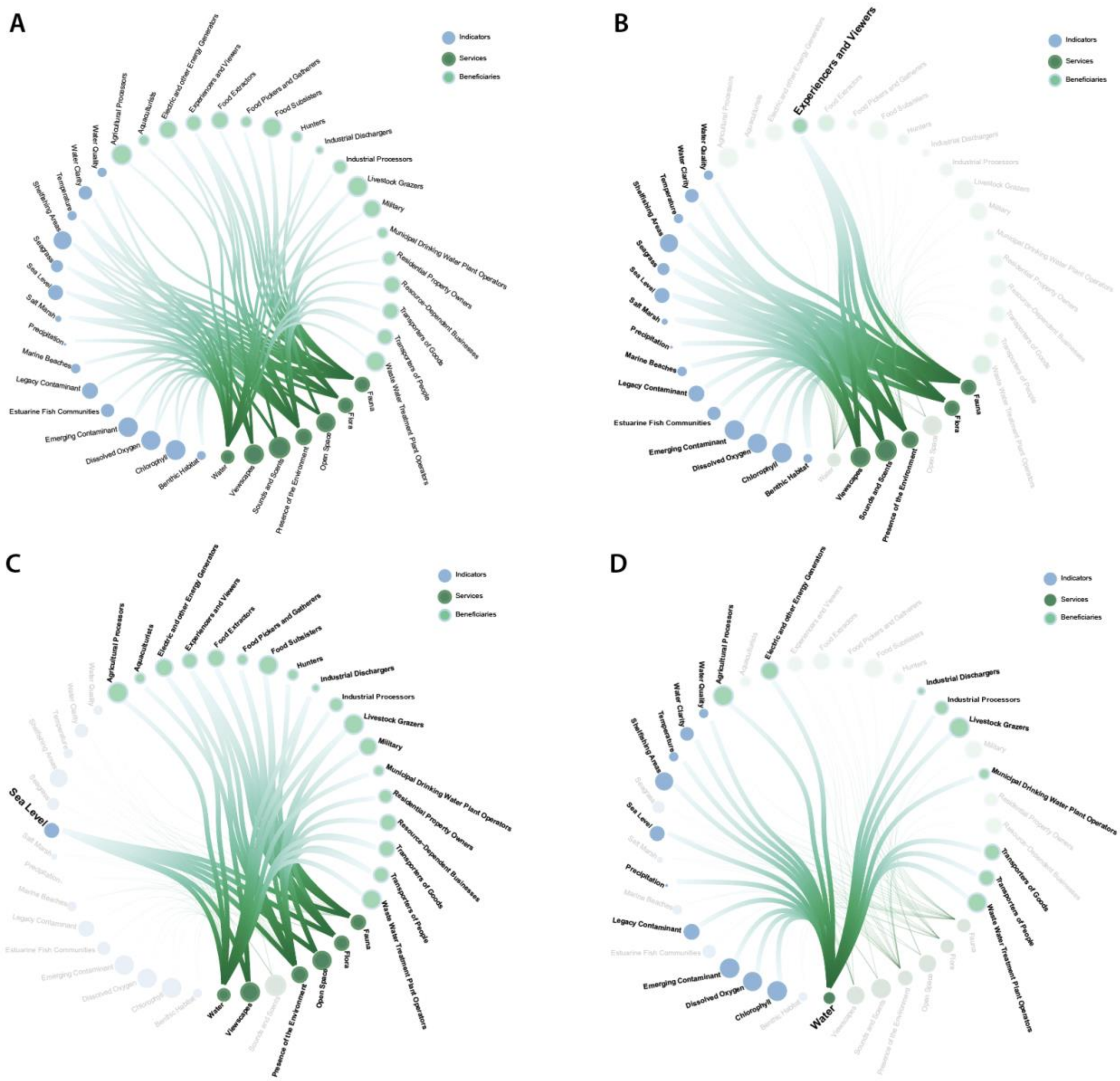


*Figure 2 - A. Preliminary schematic IESF showing the interconnectivity between **Ecosystem Goods and Services**, **Beneficiaries**, and **Indicators and Metrics**. B. The connections made when entering the IESF as Experiencers and Users (**Beneficiaries**). C. The connections made when entering the IESF from Sea Level (**Indicators and Metrics**). D. The connections made when entering the IESF from Water (**Ecosystem Goods and Services**). The Near Coastal Marine and Estuaries Final Ecosystems Goods and Services (FEGS) from the EPA FEGS Query Tool were used to define **Ecosystem Good and Services (ESVs)** and **Beneficiaries** and the **Indicators and Metrics** were taken from the Narragansett Bay Estuary Program State of Narragansett Bay and Its Watershed report (see figure 2, Narragansett Bay Estuary Program, 2017).*

This preliminary schematic was presented to both SNEP Subcommittees at a meeting held January 22, 2020 in Lakeville MA. We presented the schematic as an initial static visualization that demonstrates the relational interconnectivity between IESF components that would be versatile enough to be useful to various types of users (e.g., scientists, municipal managers, the public). We explained that this visualization code could be adapted to be web-based and interactive in the future so that it would be more dynamic and responsive to user exploration. For example, in a web-based version, each element would be clickable, and might expand and contract hierarchically depending on the level of detail selected by the user. One example of this would be how *Sea Level*, *Temperature*, and *Precipitation* indicators could all be collapsed under a ***Resilience*** indicator category (i.e., the "default" view would show ***Resilience Indicators*** and the user would click on that element to reveal the various individual indicators and metrics relevant to ***Resilience***). Other features in a web-based version of the IESF visualization could include the association of various attributes (e.g., valuations, number of beach visits, etc.) with each IESF component/element to provide the user with additional information (i.e., click each indicator to show "score", "status" or value in SNEP region).

Feedback from the Subcommittees on January 22 regarding the draft IESF visualization was positive. A few questions and suggestions to carry through the rest of the IESF development effort arose:

- Can research questions fit within the IESF network diagram and if so, how?
    - The databases/spreadsheets used for constructing the network diagram can be modified to include additional groups and subgroups as well as their connectivity and any attributes of interest to SNEP stakeholders.
    - To include specific research questions, an additional top-level category (e.g., "Research Questions") can be created in the database and each row (or connection) could have a research question associated with it. Like the other top-level categories (**Ecosystem Goods and Services**, **Beneficiaries**, and **Indicators and Metrics**), there can be a similar hierarchical structure of groups and subgroups for the research questions depending on the desired level of detail or relevance. This structure would allow a user to query the IESF by research question to identify whether one or multiple **Ecosystem Goods and Services**, **Beneficiaries,** and/or **Indicators and Metrics** are relevant to the research question of interest. This organizational framework would allow SNEP to track research questions of interest.
- Can the IESF network diagram be more than a qualitative tool (e.g., can ecosystem service valuations be considered)?
    - Although the short answer to this question is "yes", a high level of effort would be required to implement this concept. The databases/spreadsheets used for constructing the network diagram can be modified to include any attributes of the ecosystem service, beneficiary, or indicator of interest to SNEP stakeholders and can be visualized in the IESF network diagram (i.e., colors, shapes, and sizes could be used to display quantitative attributes). However, it would be important to ensure that any quantitative values displayed on the IESF schematic were developed using consistent methods and that the values are truly comparable among all components. In practice this is very difficult to accomplish for multiple ecosystem service valuations, for example.
- How can the IESF and associated database(s) be maintained and updated for future use (e.g., can the IESF and databases be hosted on a data portal)?

    - A relatively high level of effort would be required to develop tools to enable community members to add or edit the IESF and associated databases. In the near-term, the IESF and associated database are meant to serve as an internal set of tools that is used by SNEP staff and technical experts to organize the vast array of information about **Ecosystem Goods and Services**, **Beneficiaries,** and/or **Indicators and Metrics** in the SNEP region. A medium level of proficiency with Microsoft Excel is required to maintain and update the IESF database.
- Maintaining a narrow scope will make the IESF more useful to users (e.g., prioritize SNEP region services and only include the highest priorities in the IESF).

2. *Ecosystem Goods and Services, Beneficiaries, and Indicators and Metrics in the SNEP region*

We also solicited input from both SNEP Subcommittees at the Jan 22 meeting regarding which **Ecosystem Goods and Services**, **Beneficiaries**, and **Indicators and Metrics** should be included in the SNEP IESF.

Meeting attendees were divided into two (2) groups ensuring that members of each Subcommittee were in each group. The same list of seven (7) ecosystems services (from the "near coastal marine and estuarine" FEGS in the EPA FEGS Query Tool) were provided to each group. Each group worked on the same flow diagram (**Beneficiaries ⇔ Ecosystem Goods and Services ⇔ Indicators and Metrics**) from opposite directions: during the first portion of the group activity, Group 1 identified SNEP region beneficiaries of those ecosystem services while Group 2 identified indicators and metrics of those ecosystem services measured in the SNEP region; then, Group 1 identified indicators and metrics of the services the beneficiaries care about while Group 2 identified SNEP region beneficiaries of those ecosystem services described the indicators identified. The groups were also asked to expand and/or refine the initial list of ecosystem services provided at the outset so that they would better represent SNEP ecosystem services. The activity resulted in two (2) **Beneficiaries ⇔ Ecosystem Goods and Services ⇔ Indicators and Metrics** flow diagrams (Figure 3) that not only identified SNEP priorities and nomenclature, but the beginning stages of a hierarchy and connectivity structure that could be used to further develop the IESF structural concept.

Figure 3. Resulting **Beneficiaries ⇔ Ecosystem Goods and Services ⇔ Indicators and Metrics** flow diagrams created by Group 2 (top) and Group 1 (bottom). Pink notes: Ecosystem Services. Orange Notes: Indicators and Metrics. Blue Notes: Beneficiaries.

The Subcommittee members described hundreds of elements within **Ecosystem Goods and Services**, **Beneficiaries**, and **Indicators and Metrics**. One group explicitly differentiated between environmental indicators and social/economic indicators. Environmental indicators reflect the condition or status of an ecosystem service or environmental component (e.g., "acres of shellfish habitat" reflects how many shellfish might be available for harvest) whereas social/economic indicators reflect the degree to which an ecosystem service is actually used by people (e.g., "shellfish landings" reflect how many shellfish are actually harvested by people). The Subcommittees felt that it was important to capture both types of indicators in the SNEP IESF. Both groups also articulated a preference for simple terminology to describe ecosystem services within the IESF. They felt that grouping services by categories such as "provisioning", "regulating/protecting", and cultural/recreational" was clearer and could be understood by broader audiences.

We compiled the feedback from the Subcommittees into the relational database (Excel spreadsheet). Subcommittee members typically suggested **Ecosystem Goods and Services**, **Beneficiaries**, and **Indicators and Metrics** at a very fine level of detail. For organizational purposes, we binned their suggestions into groups and subgroups for each of the components (**Ecosystem Goods and Services**, **Beneficiaries**, and **Indicators and Metrics**). For example, *Fish for consumption* was a suggested Ecosystem Good and Service, and we grouped it with other *Animals for consumption* in Subgroup 2, and with other *Food* in Subgroup 1, and finally with all other ***Provisioning Services***. This group and subgroup hierarchy (Figure 4) keeps the complex relationships organized and allows users to expand or contract the IESF schematic to the level of their interest. The purpose of Figure 4, which shows four rows from each top-level group and the hierarchical structure (groups and subgroups) for **Ecosystem Goods and Services** (green), **Beneficiaries** (blue), and **Indicators and Metrics** (red), is merely to provide a visual excerpt of the much larger IESF relational-database (which is provided as a separate Excel file). The Near Coastal Marine and Estuaries Final Ecosystems Goods and Services (FEGS) from the EPA FEGS Query Tool are included as a relational reference for **Ecosystem Goods and Services** and **Beneficiaries** used for the IESF developed here and those used in the EPA FEGS Query Tool.

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 4. Excerpts from the IESF Relational Database illustrating the Group and Subgroup hierarchy. 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 4 Subgroups in the event that additional components are added in the future. **Ecosystem Goods and Services Group** and Subgroup 1 components were taken from The Economics of Ecosystems & Biodiversity (TEEB) (McVittie and Hussain, 2013). As reference, equivalent FEGS Scoping Groups have been included for **Ecosystem Goods and Services** and **Beneficiaries**.*

To address the Subcommittees' feedback about nomenclature, the Group and Subgroup 1 for **Ecosystem Goods and Services** were taken from The Economics of Ecosystems & Biodiversity or TEEB (McVittie and Hussain, 2013), while Subgroups 2-4 reflect SNEP region-specific goods and services. The TEEB global initiative builds on the ideas developed in the Millennial Ecosystem Assessment (2005) and aims to promote the understanding of the economic value of ecosystem services. Although the database uses the TEEB terminology, the FEGS terminology for **Ecosystem Goods and Services** and **Beneficiaries** is retained as a cross-walk between the two systems and to provide consistency with other EPA initiatives.

Overall, the database was populated with ~760 relationships between SNEP region-related **Ecosystem Goods and Services**, **Beneficiaries**, and **Indicators and Metrics**. This number of connections exceed our expectations for what the Subcommittees might provide in order to demonstrate and test the structure and components of the IESF and a functional schematic (discussed below). Despite its size, the database is filterable and sortable and designed for easy maintenance and modification. It is important to note that the database is not intended to be public facing or publicly accessible. Its purpose is to act as a mechanism to compile, store, and organize the structural components necessary to express the relationships between and among **Ecosystem Goods and Services**, **Beneficiaries,** and **Indicators and Metrics**, as well as to construct the IESF schematic. The database can be modified or updated based on the needs of SNEP stakeholders by SNEP staff or future contractors.

3. Development of a functional IESF Schematic

Using the IESF relational database and building on the draft IESF visualization, we developed a functional SNEP IESF schematic that captures the hierarchical structure and interconnectivity of the database components (Figure 5; Details regarding the construction of the schematic, including the R code, can be found in Appendix 1).The SNEP IESF functional schematic consists of three concentric rings. 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 in this initial static version of the IESF schematic 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).

Even with this minimal level of detail in the example functional schematic, it is apparent that the hierarchical ring structure can provide the "expansion and contraction" aspect of the framework that allows the user to define their level of interest and detail. For example, in a dynamic, web-based version of this schematic, the next ring(s) could be "revealed" when a user clicks on a Subgroup in the innermost ring. Similar to the draft visualization, attribute information could be added to the database so that when a user clicks on an indicator or ecosystem service, a score/value or research question (or some other attribute) is displayed.

After reviewing the draft visualization, the Subcommittees indicated that "entering" the IESF schematic from various perspectives or components would be a critical feature to retain in the final version. We have retained that ability in the functional schematic by color-coding the components within the ring structure. In addition, the code that generates the functional IESF schematic has been adapted so that custom "versions" of the schematic can be generated that show only those relationships/connections around a component or element of interest. In the following section, we describe example uses of three different custom "versions" of the IESF schematic that display relationships of different focal components.

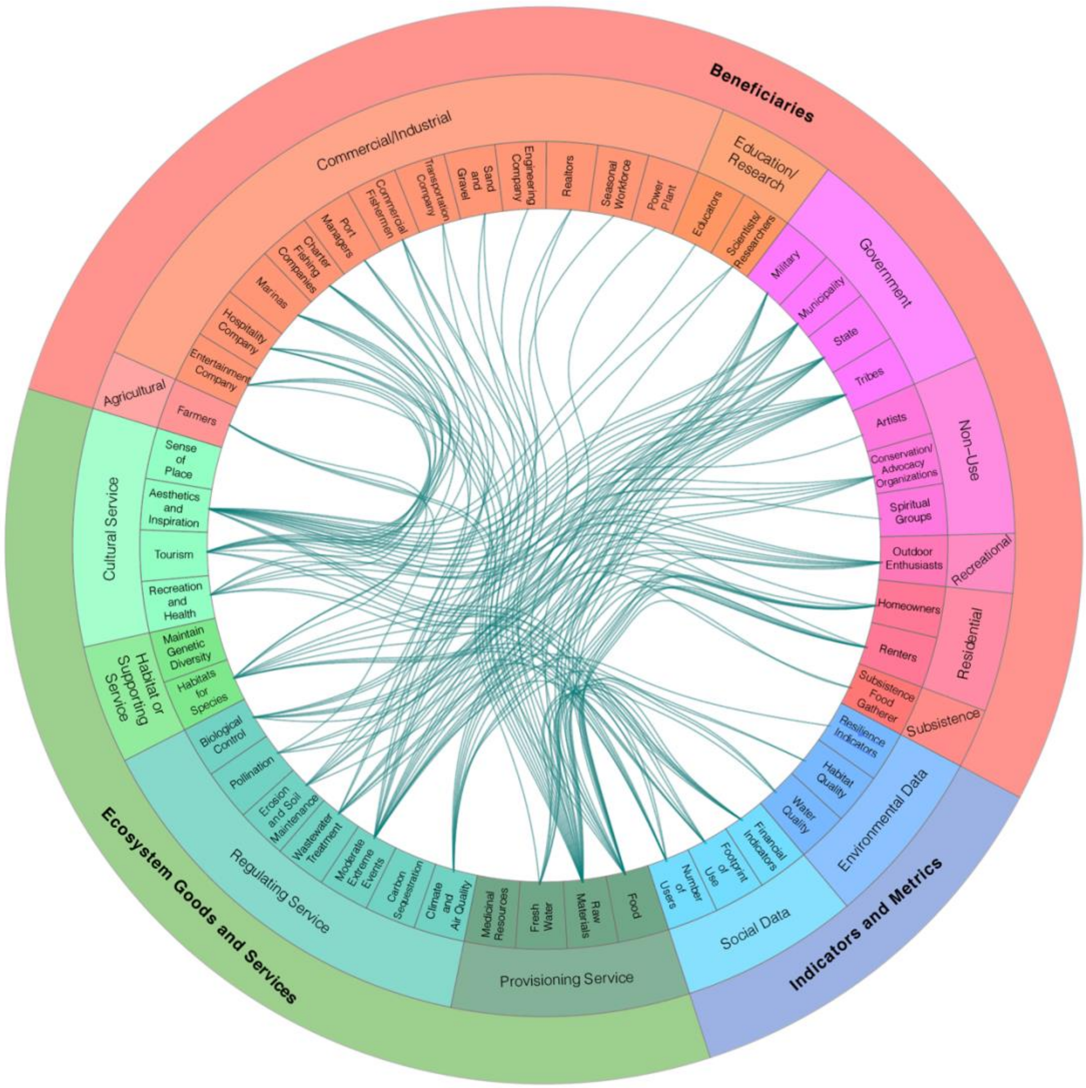


Figure 5. Conceptual SNEP region IESF functional schematic illustrating the hierarchical structure and interconnectivity of the IESF relational database components. Schematic construction details, including the R code, can be found in Appendix 1.

4. IESF Use Examples

This section is intended to provide a few examples of how the functional IESF schematic could be used by different stakeholders to address their own objectives. Realizing that these examples are limited in their scope, there is still a need to demonstrate the "operationalization" of the IESF, in other words, how SNEP and its stakeholders would use the IESF to support the development and/or implementation of SNEP's monitoring strategy. Since the results of other tasks in this contract are required to fully illustrate that operationalization, this contract's final report will synthesize the results of all relevant tasks and provide a detailed example.

Member of the General Public

This example demonstrates entry into the schematic as a Commercial Fisherman (**Beneficiary**) and the relevant connections to **Ecosystem Goods and Services** and **Indicators and Metrics** (Figure 6). Following these connections, it is clear that the Fisherman should care about such ***Regulating Services*** and ***Habitat or Supporting Services*** as *Wastewater Treatment* and *Habitat for Species*, respectively. The schematic makes clear that his or her livelihood depends on maintaining a certain level of water quality and the presence of habitat for whichever species he or she is most interested in. The Fisherman can understand his or her role in the IESF (and the community in general) as providing a ***Provisioning Service*** through the delivery of *Food* and possibly other *Raw Materials*. Finally, the Fisherman can look for Indicators and Metrics about how suitable the water body is for his or her activities (***Environmental Data*** – *Water Quality*) or how robust and productive the fishing industry might be (***Social Data***).

Practitioner

This example demonstrates a potential entry point from a management and decision-making perspective. For instance, a state agency with a water quality monitoring program might enter the schematic at *Water Quality* (**Indicators and Metrics**) (Figure 7) to compile a list of **Beneficiaries** in their jurisdiction in order to conduct a valuation of the market and non-market assets (i.e., societal value) as justification for funding requests to implement best management practices. The schematic would also show them the possible **Ecosystem Goods and Services** that directly impact their **Beneficiaries** and implement best management practices (e.g., Wastewater Treatment – ***Regulating Service***) to protect such ***Provisioning Services*** as *Food* and *Raw Materials*.

Advocacy Organization

This example demonstrates entry into the schematic from the perspective of an organization interested in advocating for the local food movement. This organization may enter the diagram by highlighting *Food* as a ***Provisioning Service*** (Figure 8) and compile a list of **Beneficiaries** to consider when developing educational and outreach materials. They may also see connections to ***Social*** and ***Environmental Indicators*** that reflect how well this service is being delivered currently (e.g., *Financial Indicators*) and if the condition of the environment is supportive of local food (e.g., *Water Quality*)

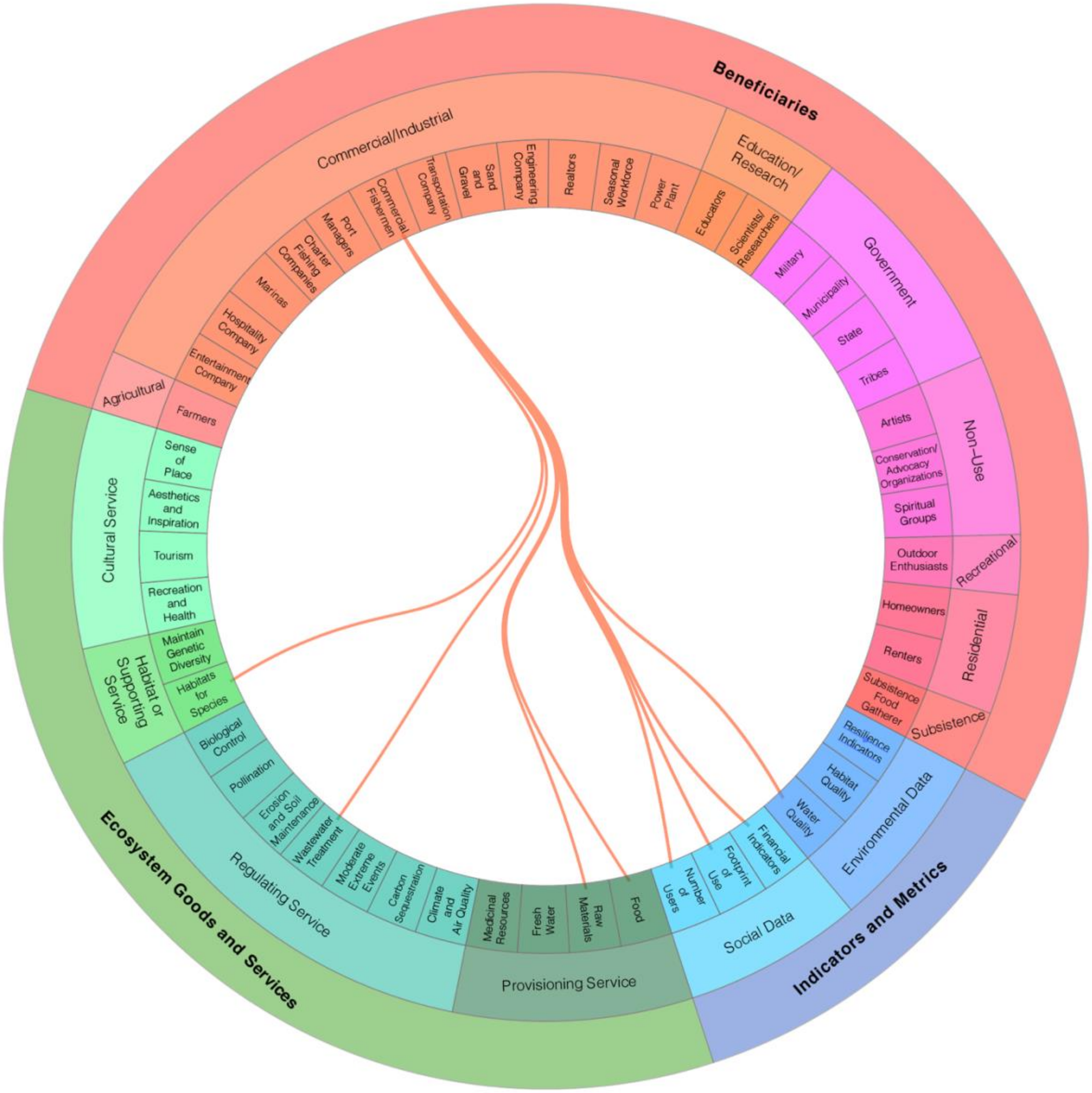


*Figure 6. Commercial Fishermen (**Beneficiaries**) entry point and relevant connections to **Ecosystem Goods and Services** and **Indicators and Metrics**.*

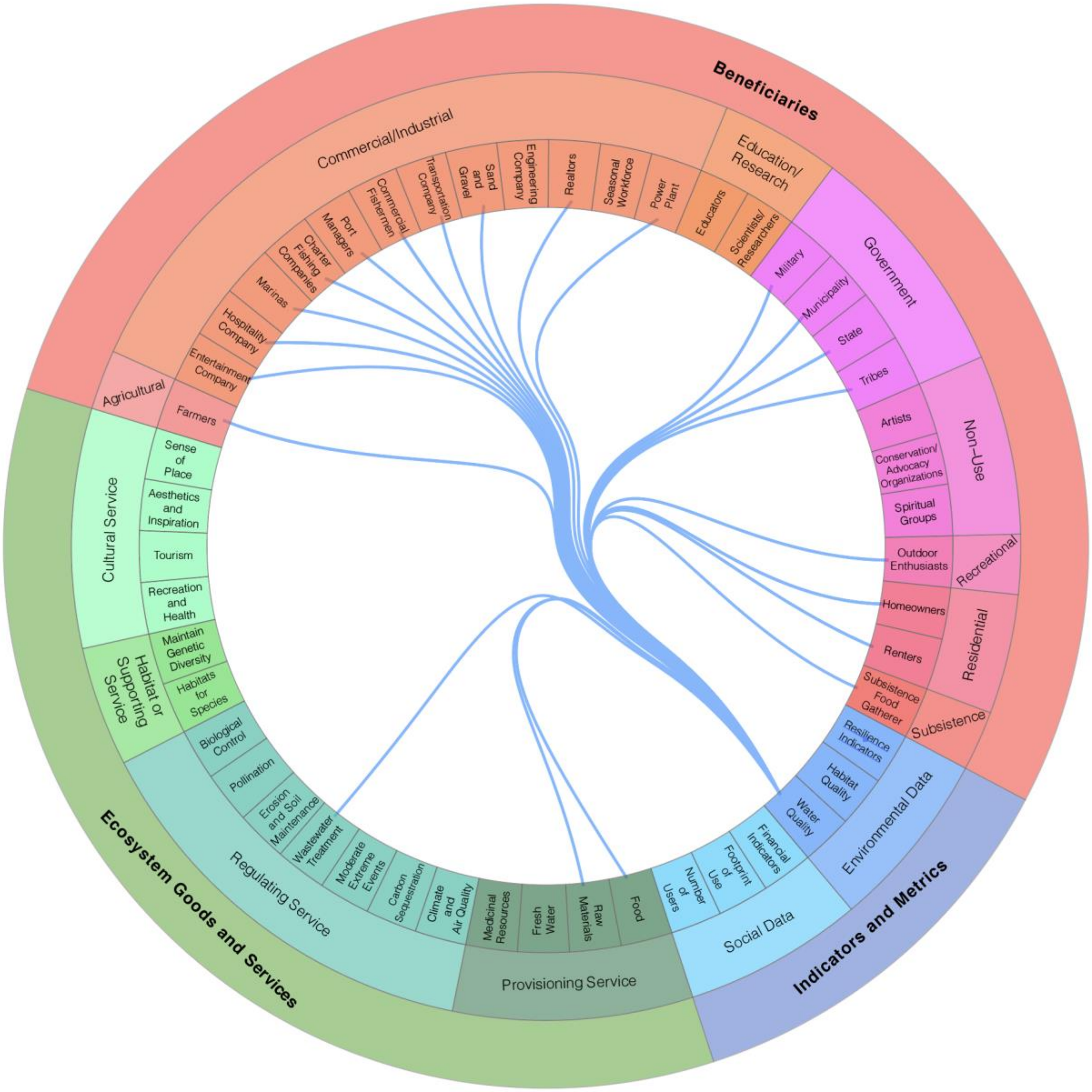
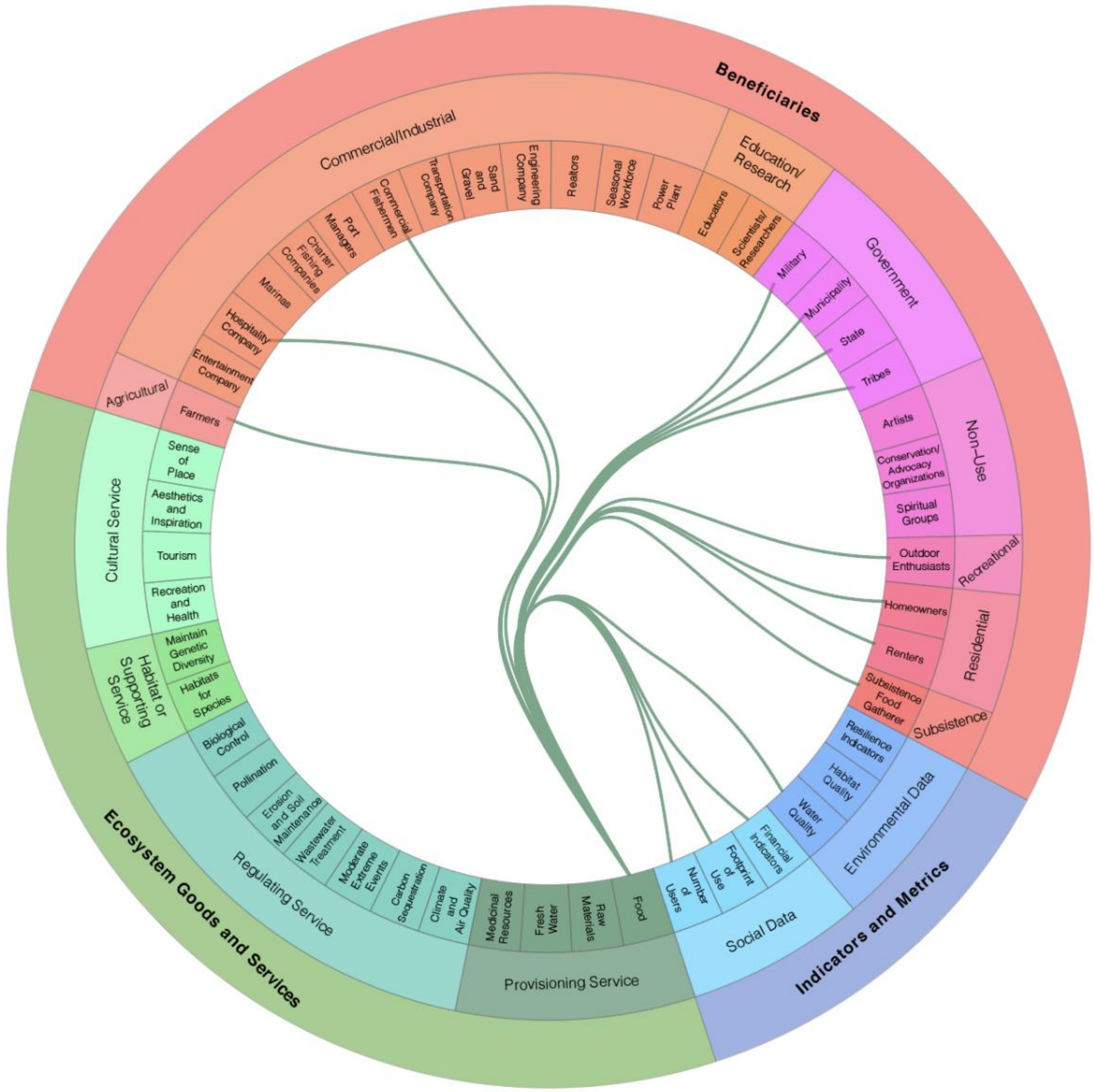


*Figure 7. Water Quality (**Indicators and Metrics**) entry point and relevant connections to **Ecosystem Goods and Services** and **Beneficiaries**.*



5. Lessons learned and recommendations

The goal of **Task 2.B.** was to develop a functional schematic of a SNEP region Integrated Ecosystem Services Framework (IESF) that represents a conceptual visualization of 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. That functional schematic is presented here in addition to a relational database which includes the SNEP Subcommittees' extensive input regarding the relevant components on the IESF.

Lessons learned

- The quantity of relationships between and among **Ecosystem Goods and Services**, **Beneficiaries**, and **Indicators and Metrics** is and will be very large, even if the database is limited to coastal and estuarine services.
- Although the majority of the **Indicators and Metrics** in the SNEP region had referred to environmental data (e.g., nutrient concentrations, water temperature, etc.), Subcommittee members indicated that there are also a large number of social/economic indicators (e.g., beach visitations, property values, etc.) that provide important information regarding 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 to say that 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.
- The existing broad-scale FEGS terminology was not immediately intuitive to SNEP Subcommittee members. In order to increase the accessibility and understandability of the IESF, the The Economics of Ecosystems & Biodiversity or TEEB (McVittie and Hussain, 2013) terminology was used for top-level and Group category names.
- The static IESF schematic presented in this report meets the goals of the project by providing a functional schematic that is capable of illustrating the complex relationship between SNEP region **Ecosystem Goods and Service**, their **Beneficiaries**, and the **Indicators and Metrics** used to track them; however, it quickly becomes clear that the abundance of information populating the relational database and the schematic limit the usability of a static image. It is evident that the usefulness of the IESF schematic would be significantly improved either by generating several different versions of the schematic for various focal topics/issues, or by developing a dynamic, web-based interactive visualization that might expand and contract as the user navigates through their entry point(s) of interest (see additional comment on this in Recommendations, below).

Recommendations

With respect to the further development of the schematic and the database, we recommend the following actions:

1) Add all program and project inventory data (i.e., from Tasks 2A and 4A) to the IESF database and ensure that the nomenclature is consistent with SNEP projects and other regional programs. Elements suggested by Subcommittee members at the January 22 meeting that are not reflected in current programmatic or project-level monitoring should be maintained in a separate portion of the database for future use, if desired. These suggestions (because they represent elements not currently being measured in the SNEP region) could represent data gaps or areas of future work.

2) Further refine the R scripts used to create the IESF to allow the user to define the desired schematic components (if known) and eliminate the need for calls to external applications. This would include imbedding the IESF relational database in the R project files, appropriately sizing and positioning figure labels and hierarchy rings, and creating user entry point connection tables.

3) Reduce visual clutter in the diagram. As mentioned above, the current schematic is a static figure that allows users to see several levels of the IESF hierarchy via the outer rings. As more rings (i.e., Subgroups) get added to the IESF, the figure becomes increasingly crowded and difficult to view and interpret. This can be addressed in two ways. One immediate and relatively

low-effort option is to generate several different "versions" of the schematic for various focal topics/issues by simply filtering the IESF database and extracting only the relevant Indicators and Metrics, Ecosystem Goods and Services, and Beneficiaries for display. This idea was tested successfully for this project and examples are provided in Figures 6-8. A higher effort option would be to create a dynamic, web based IESF schematic. A dynamic and interactive IESF hosted on the SNEP webpage would provide increased functionality and user control to address individual user needs/interests. We found two (2) existing examples of dynamic and interactive schematics that could help demonstrate the value of developing an interactive SNEP IESF: Mapping Science Journal Citations and Concept Map. See Appendix 2 for static images and brief descriptions for each of these examples (Figures A2 - 1 and A2 - 2, respectively). In order to create a dynamic and interactive schematic, the existing database would sufficiently provide the structural components, but a web development programming language (e.g., JavaScript, Python) would need to be used to incorporate animated transitions and interactive content.

Following discussion with SNEP staff about the relatively high level of effort likely required to develop an interactive web-based schematic, it was determined that this was not a priority at this time. At a minimum, the IESF should be tested and used internally by SNEP prior to discussions about if or how it could be used as public-facing communication tool. In addition, questions remain regarding where a web-based IESF would be hosted, how it and the IESF relational database would be maintained, and how it would be made accessible to SNEP stakeholders.

6. References Cited

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APPENDIX 1: SNEP IESF Conceptual Diagram Construction Report

SNEP IESF Conceptual Diagram

Edge Bundling and Hierarchy

This document shows how parts of the **SNEP Integrated Ecosystem Services Framework (IESF) Conceptual Diagram** were created. At this stage, the major components of the diagram were created in RStudio and assembled in Adobe Illustrator. This report will show the *Edge Bundling* and the *Hierarchical Structure*.

Below you'll find pieces of the R code used to construct a **Network Diagram**. An explanation of the intent of the code will be provided for context along with citations where appropriate.

The data used in this diagram originates from the **SNEP Region IESF Relational Database** which outlines the hierarchical structure between *Ecosystem Goods and Services*, *Beneficiaries*, and *Indicators and Metrics*.

Step 1 - Loading the R Libraries

Here we load all of the libraries that are required for the different functions that will be called in the code.   Not all of these libraries are critical, but it might be helpful to have them loaded in case you want to modify the code.

```
library(ggraph)
library(igraph)
library(tidyverse)
library(RColorBrewer)
library(ggforce)
library(tidygraph)
library(circlize)
```

Step 2 - Loading the Data and Making Connections

At this stage we are loading the EXCEL CSV files that contain the individual components of the IESF Relational Database. In this case, three (3) different files were loaded based on their hierarchy (i.e., Group, Subgroup, Subgroup1, etc.). These files can be defined by the user, but they need to show two (2) columns labelled "from" and "to", respectively, because they establish the hierarchical connections. For example, the following code loads the Group to Subgroup components and connections:

```
d2 <- data.frame(read.csv("./Data files/IESF-Group.csv", header=T, as.is=T))

d2
```

```
##from                          to
## 1 Ecosystem Goods and Services            Provisioning Service
## 2 Ecosystem Goods and Services            Regulating Service
## 3 Ecosystem Goods and Services            Habitat or Supporting Service
## 4 Ecosystem Goods and Services            Cultural Service
## 5                   Beneficiaries            Agricultural
## 6                   Beneficiaries       Commercial/Industrial
## 7                   Beneficiaries          Education/Research
## 8                   Beneficiaries              Government
## 9                   Beneficiaries                 Non-Use
## 10                  Beneficiaries            Recreational
## 11                  Beneficiaries             Residential
## 12                  Beneficiaries             Subsistence
## 13        Indicators and Metrics        Environmental Data
## 14        Indicators and Metrics               Social Data
```

The following code shows all of the data files that are loaded and then combines them into one object that we've called "edges". In network diagrams, **Edges** refer to the *hierarchical connections* between the **Groups** and **Subgroups**.

```
d1 <- data.frame(read.csv("./Data files/IESF-Origin.csv", header=T, as.is=T))
d2 <- data.frame(read.csv("./Data files/IESF-Group.csv", header=T, as.is=T))
d3 <- data.frame(read.csv("./Data files/IESF-Subgroup1.csv", header=T, as.is=T))
edges <- rbind(d1, d2, d3)
```

The next line of code creates the *relational connections* between the individual components called **Vertices**. This builds the connections between all the *Ecosystem Goods and Services* and their *Beneficiaries* and *Indicators and Metrics*.

```
connect <- data.frame(read.csv("./Data files/IESF-Edges.csv", header=T, as.is=T))
```

Step 3 - Creating the Vertices

In this step, we create the diagram's **Vertices** and their labels. Some code is included to arrange the labels appropriately, but I preferred to recreate and reorient the labels in Illustrator later.

```
## Create a vertices data.frame. One line per object of the hierarchy
vertices  <-  data.frame(
  name = unique(c(as.character(edges$from), as.character(edges$to))) , value = runif(67))
## Add a column with the group of each name. It will be useful later to color points
vertices$group  <-  edges$from[ match( vertices$name, edges$to ) ]
```

```
##Add information concerning the label to be added: angle, horizontal adjustment
## and potential flip
## First calculate the ANGLE of the labels
vertices$id <- NA
myleaves <-which(is.na(match(vertices$name, edges$from)))
nleaves <- length(myleaves)
vertices$id[ myleaves ] <- seq(1:nleaves) vertices$angle<-90- 360* vertices$id/
nleaves

## Then calculate the alignment of labels: right or left
## If I am on the left part of the plot, my labels have currently an angle < -90
vertices$hjust <- ifelse( vertices$angle < -90, 1, 0)


## Now flip the angle BY to make them readable
vertices$angle<-ifelse(vertices$angle< -90,vertices$angle+180,vertices$angle)
```

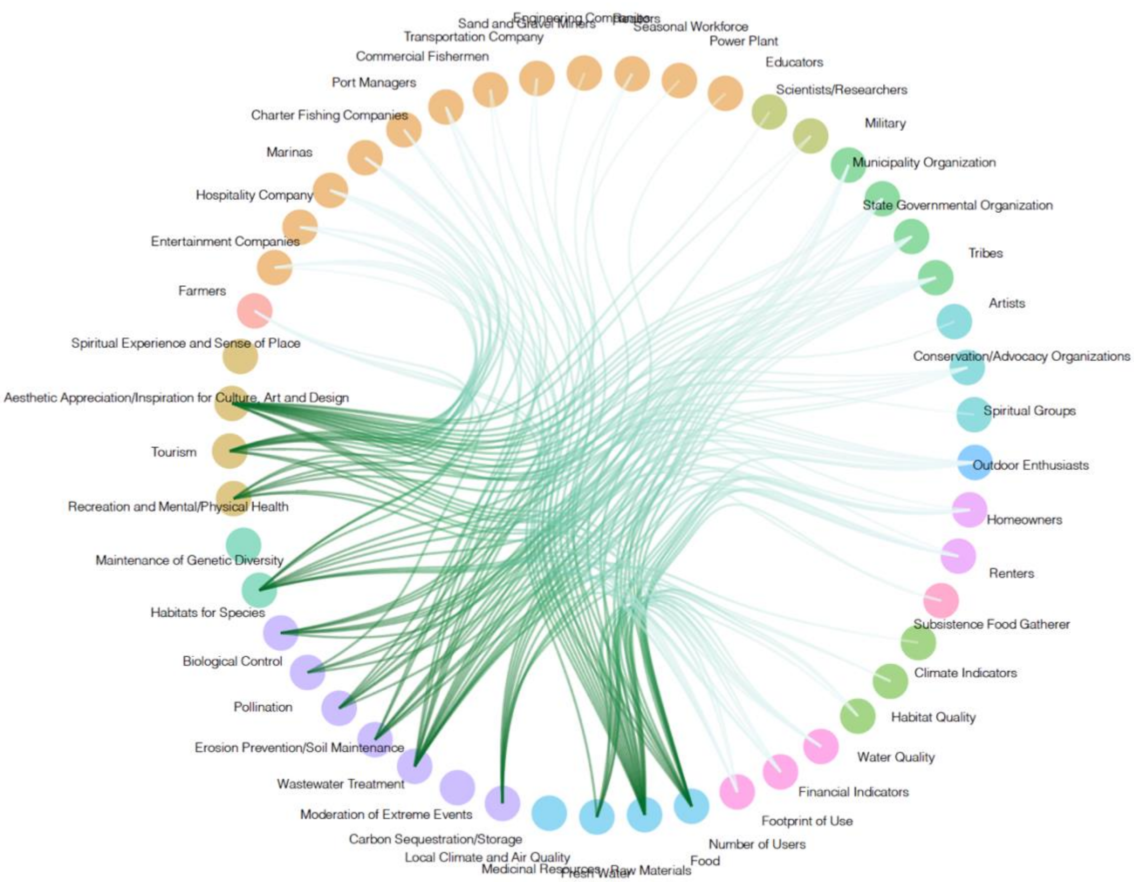
Step 4 - Creating the Diagram

The code below creates connections between the different **Subgroup1** components (vertices) of the relational database and plots the diagram. The diagram does not yet show the complete hierarchy, but the colors of the vertices do correspond to the **Group** level.

```
# Create a graph object
mygraph <- igraph::graph_from_data_frame(edges, vertices=vertices)
## The connection object must refer to the ids of the leaves:
from  <-  match( connect$from, vertices$name)
to  <-  match( connect$to, vertices$name)

ggraph(mygraph, layout = 'dendrogram', circular = TRUE) +
  ## creating the nodes for the vertices and coloring them based on the upper level group
  geom_node_point(aes(filter=leaf, x=x*1.00, y=y*1.00, colour=group, size=0.99,
                      alpha=0.2)) +
  ## bundling the connections
  geom_conn_bundle(data=get_con(from=from, to=to), alpha=0.5, width=0.5,
                   show.legend = FALSE, aes(colour=..index..), tension=0.6) +
  ## setting the color palette of the connections
  scale_edge_colour_distiller(palette = "BuGn") +
  ## creating the text for the vertices
  geom_node_text(aes(x = x*1.15, y=y*1.15, filter = leaf, label=name), size=2,  alpha=1) +
  coord_fixed() +
  theme_no_axes() +
```

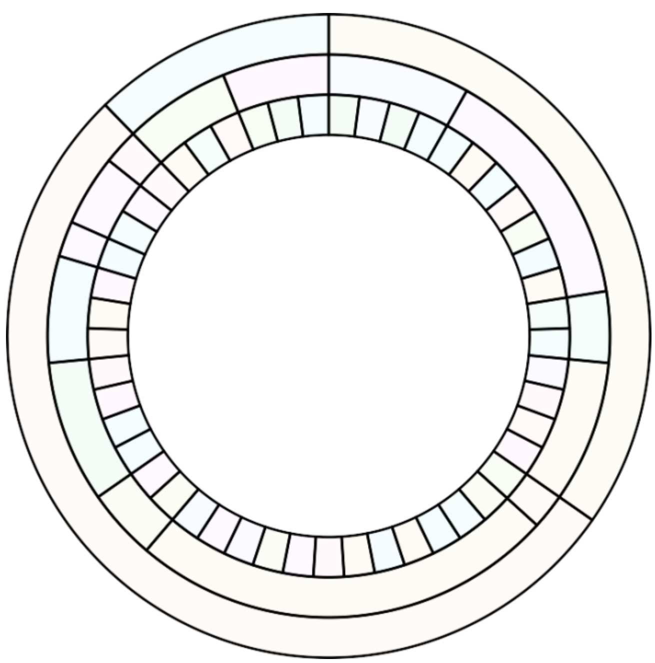
Appendix 1 - 3

```
scale_size_continuous( range = c(0.1,10) ) +
scale_y_continuous(breaks = NULL) +
theme_void() +
theme(
  legend.position="none",
  plot.margin=unit(c(0,0,0,0),"cm"),) +
guides(size=FALSE) + guides(alpha=FALSE) + labs(colour="") +
expand_limits(x = c(-1.5, 1.5), y = c(-1.5, 1.5))
```



In the next chunk of code, we create *arc bars* to represent the upper levels of the hierarchy (e.g., **Group** and **Subgroup**).

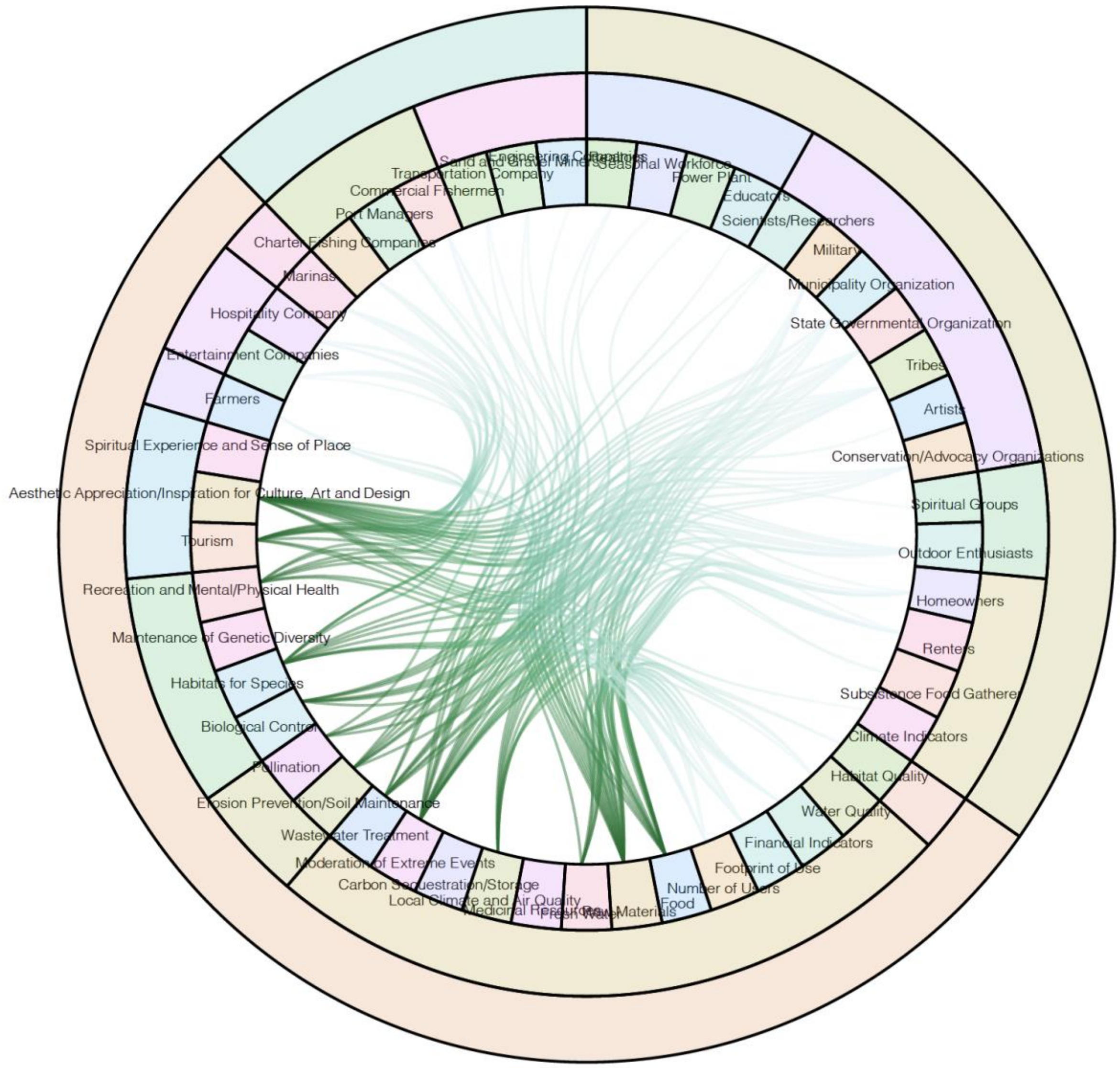
```
d2$amount <- c(4, 7, 2, 4, 1, 12, 2, 4, 3, 1, 2, 1, 3, 3)
d3$amount1 <-rep(c(1),each=49)
d1$amount2 <- c(17, 26, 6)

ggraph(mygraph, layout = 'dendrogram', circular = TRUE) +

  ## arc_bar for Group
  geom_arc_bar(aes(x0 = 0, y0 = 0, r0 = 1.4, r = 1.6, amount = amount2, fill = d1$to), alpha =
               0.2, data = d1, stat = 'pie', show.legend = FALSE) +

  ## arc_bar for Subgroup
  geom_arc_bar(aes(x0 = 0, y0 = 0, r0 = 1.2, r = 1.4, amount = amount, fill = d2$to), alpha =
               0.2, data = d2, stat = 'pie', show.legend = FALSE) +

  #arc_bar for subgroup1
  geom_arc_bar(aes(x0 = 0, y0 = 0, r0 = 1.0, r = 1.2, amount = amount1, fill = d3$to), alpha =
               0.2, data = d3, stat = 'pie', show.legend = FALSE) +

  coord_fixed() +
  theme_no_axes() +

  scale_size_continuous( range = c(0.1,10) ) +
  scale_y_continuous(breaks = NULL) +

  theme_void() +
  theme(

    legend.position="none",
    plot.margin=unit(c(0,0,0,0),"cm"),) +

  guides(size=FALSE) +
  guides(alpha=FALSE) +
  labs(colour="") +

  expand_limits(x = c(-1.5, 1.5), y = c(-1.5, 1.5))
```



Appendix 1 - 5

Now we can combine the last two (2) figures to show *BOTH* the hierarchy and the connections.

```
ggraph(mygraph, layout = 'dendrogram', circular = TRUE) +

  ## bundling the connections
  geom_conn_bundle(data = get_con(from = from, to = to), alpha=0.5, width=0.5,
                   show.legend = FALSE, aes(colour=..index..), tension=0.6) +

  ## setting the color palette of the connections
  scale_edge_colour_distiller(palette = "BuGn") +

  ##         creating the text for the vertices
  geom_node_text(aes(x = x*1.15, y=y*1.15, filter = leaf, label=name), size=2, alpha=1) +

  ## arc_bar for Group
  geom_arc_bar(aes(x0 = 0, y0 = 0, r0 = 1.4, r = 1.6, amount = amount2, fill = d1$to), alpha =
               0.2, data = d1, stat = 'pie', show.legend = FALSE) +

  ## arc_bar for Subgroup
  geom_arc_bar(aes(x0 = 0, y0 = 0, r0 = 1.2, r = 1.4, amount = amount, fill = d2$to), alpha =
               0.2, data = d2, stat = 'pie', show.legend = FALSE) +

  #arc_bar for subgroup1
  geom_arc_bar(aes(x0 = 0, y0 = 0, r0 = 1.0, r = 1.2, amount = amount1, fill = d3$to), alpha =
               0.2, data = d3, stat = 'pie', show.legend = FALSE) +

  coord_fixed() +
  theme_no_axes() +

  scale_size_continuous( range = c(0.1,10) ) +
  scale_y_continuous(breaks = NULL) +
  theme_void() +

  theme(

    legend.position="none", plot.margin=unit(c(0,0,0,0),"cm"),) +

  guides(size=FALSE) +
  guides(alpha=FALSE) +
  labs(colour="") +

  expand_limits(x = c(-1.5, 1.5), y = c(-1.5, 1.5))
```



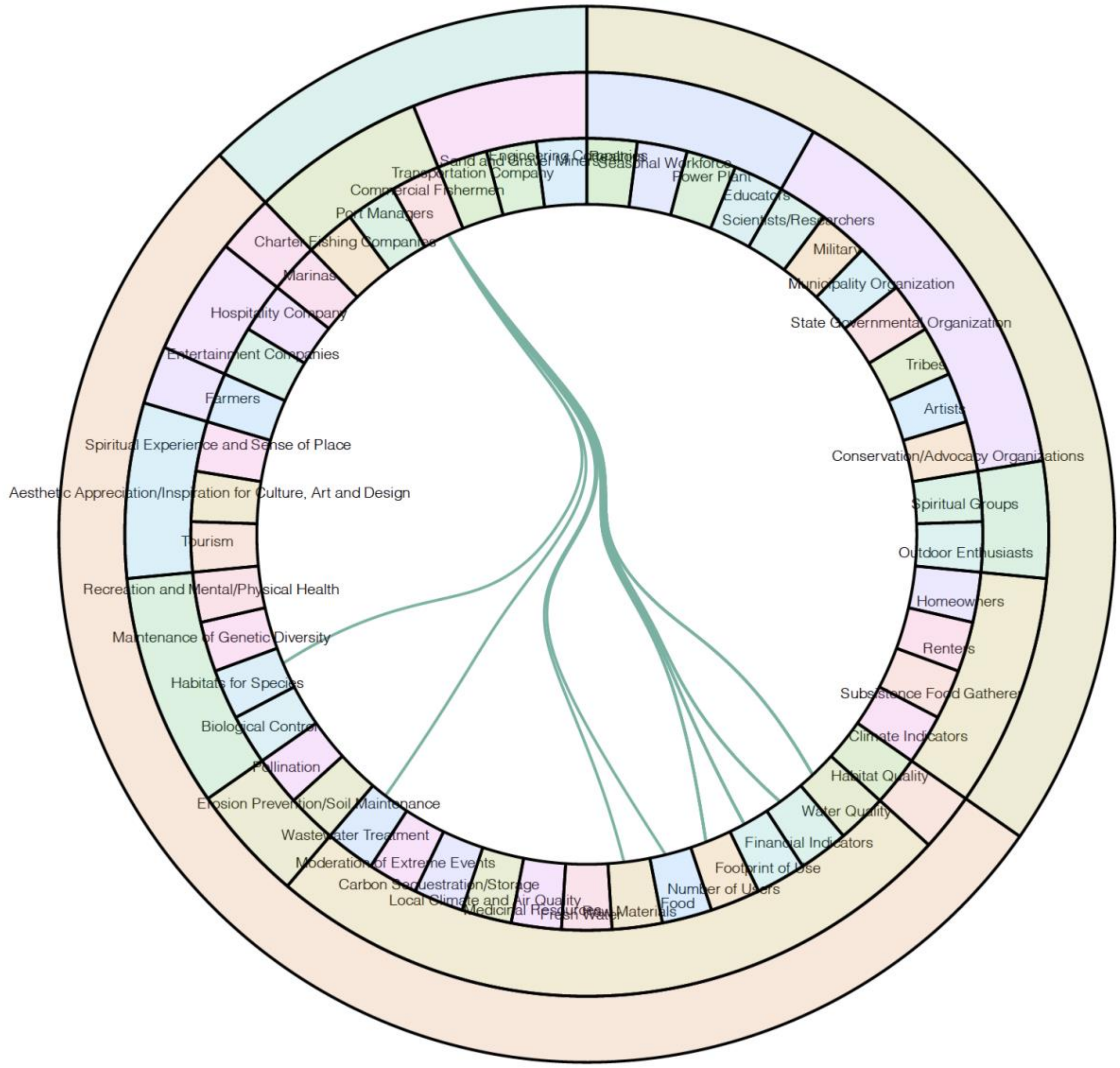
From this point, the final figure was exported as a PDF so that it could be opened in Illustrator to insert and modify the labels and colors according to their groupings. Future work could include adding the appropriate code to accomplish both of those tasks.

Step 5 - Highlighting specific connections

This framework was created to serve a broad range of users including scientists, managers, and

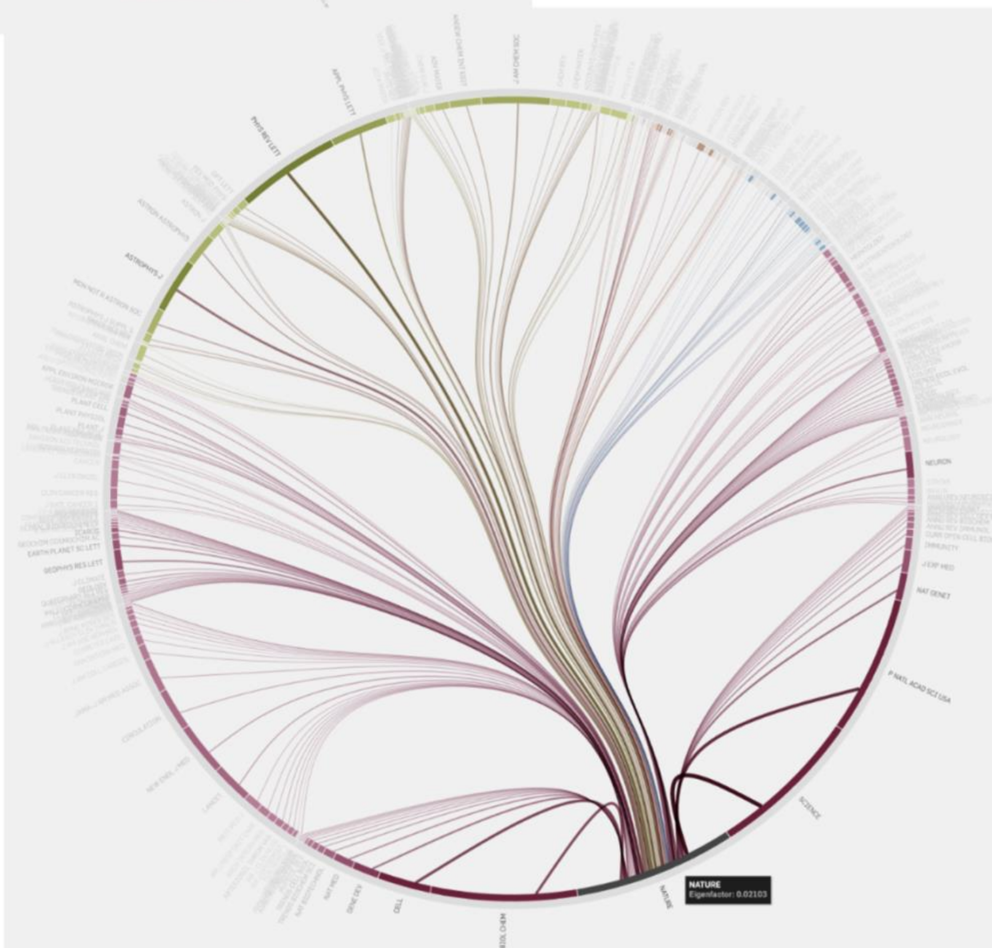
The general public. As such, the users may "enter" the framework from different points. For instance, Commercial Fisherman can enter from their block and see only the connections between **Ecosystem Goods and Services**, **Indictors and Metrics**, and themselves. The code below was created to highlight just those connections using a simple spreadsheet that has **Commercial Fisherman** (Beneficiaries) in the "from" column (column 1) and all the services and metrics in the "to" column (column 2). Other example data files are provided for entry points from **Water Quality** (Indictors and Metrics) and **Food** (Ecosystem Goods and Services). Future work could include adding the code to extract the connections for a given entry point and creating the data frame.

```
## Highlighting the connections from one (1) starting point:

## There are three (3) data files included in this porject for this demonstration

##1) connect_CF is the connections starting from Commercial Fisherman (Beneficiaries) ##2)
connect_FOOD is the connections starting from Food (Ecosystem goods and Services) ##3)
connect_WQ is the connections starting from Water Quality (Indicators and Metrics) ## the
code below is just with the connections for Commercial Fisherman but can be

## modified by changing the file name

connect_CF <- data.frame(read.csv("./Data files/connect_CF.csv", header=T, as.is=T))
from_head_CF = match(connect_CF$from, vertices$name) %>% head(16)

to_head_CF = match(connect_CF$to, vertices$name) %>% head(16)

ggraph(mygraph, layout = 'dendrogram', circular = TRUE) +

  ## bundling the connections
  geom_conn_bundle(data = get_con(from = from_head_CF, to = to_head_CF), alpha = 1,
                   colour="#69b3a2", width=0.5, tension=0.9) +

  ## setting the color palette of the connections
  scale_edge_colour_distiller(palette = "BuGn") +

  ## creating the text for the vertices
  geom_node_text(aes(x = x*1.15, y=y*1.15, filter = leaf, label=name), size=2, alpha=1) +

  ## arc_bar for Group
  geom_arc_bar(aes(x0 = 0, y0 = 0, r0 = 1.4, r = 1.6, amount = amount2, fill = d1$to),
               alpha = 0.2, data = d1, stat = 'pie', show.legend = FALSE) +

  ## arc_bar for Subgroup
  geom_arc_bar(aes(x0 = 0, y0 = 0, r0 = 1.2, r = 1.4, amount = amount, fill = d2$to),
               alpha = 0.2, data = d2, stat = 'pie', show.legend = FALSE) +

  #arc_bar for subgroup1
  geom_arc_bar(aes(x0 = 0, y0 = 0, r0 = 1.0, r = 1.2, amount = amount1, fill = d3$to),
               alpha = 0.2, data = d3, stat = 'pie', show.legend = FALSE) +

  coord_fixed() +
  theme_no_axes() +

  scale_size_continuous( range = c(0.1,10) ) +

  scale_y_continuous(breaks = NULL) +
  theme_void() +

  theme(

    legend.position="none",
    plot.margin=unit(c(0,0,0,0),"cm"),) +

 guides(size=FALSE) +
 guides(alpha=FALSE) +
 labs(colour="") +

 expand_limits(x = c(-1.5, 1.5), y = c(-1.5, 1.5))
```


Sand and Gravel Miners
Seasonal Workforce
Transportation Company
Power Plant
Commercial Fishermen
Educators
Port Managers
Scientists/Researchers
Charter Fishing Companies
Military
Marinas
Municipality Organization
Hospitality Company
State Governmental Organization
Entertainment Companies
Tribes
Farmers
Artists
Spiritual Experience and Sense of Place
Conservation/Advocacy Organizations
Aesthetic Appreciation/Inspiration for Culture, Art and Design
Spiritual Groups
Tourism
Outdoor Enthusiasts
Recreation and Mental/Physical Health
Homeowners
Maintenance of Genetic Diversity
Renters
Habitats for Species
Subsistence Food Gathere
Biological Control
Climate Indicators
Pollination
Habitat Quality
Erosion Prevention/Soil Maintenance
Water Quality
Wastewater Treatment
Financial Indicators
Moderation of Extreme Events
Footprint of Use
Carbon Sequestration/Storage
Number of Users
Local Climate and Air Quality
Food

APPENDIX 2: Example Dynamic and Interactive Web-Based Schematics

Figure A2 - 1. Screen captures of a web-based interactive visualization of a scientific journal citation network. The inset figure in the upper left-hand corner is the complete schematic and the larger figure shows the details of a singular entry point (Nature). The user can select a single journal (inner ring) or whole field (outer ring) and all citation flow coming in or out of the selection will be displayed. Movement of the cursor over any portion of the diagram provides attributes of that particular portion of the schematic. This example is a similar dynamic version of the static IESF schematic presented in this report.



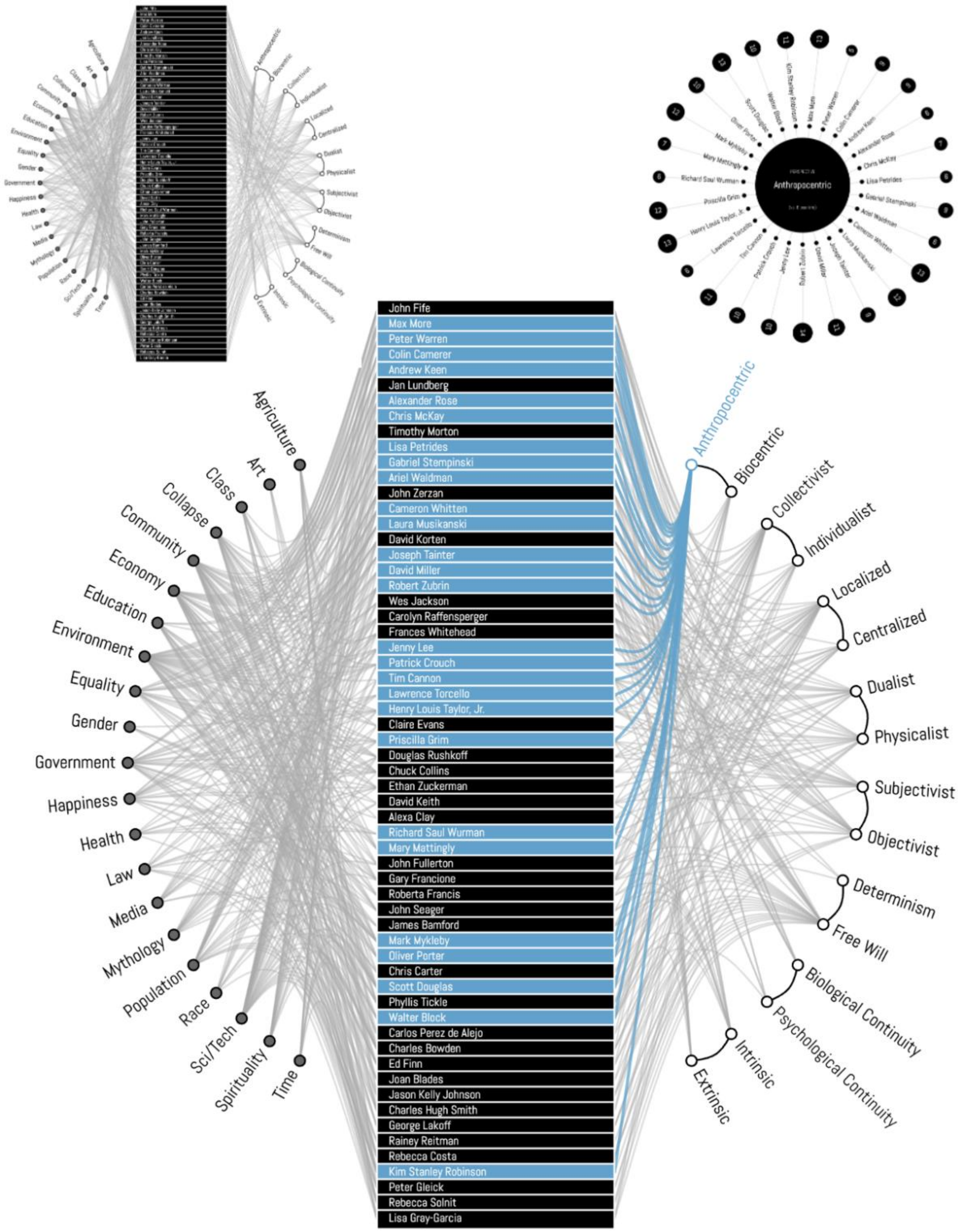


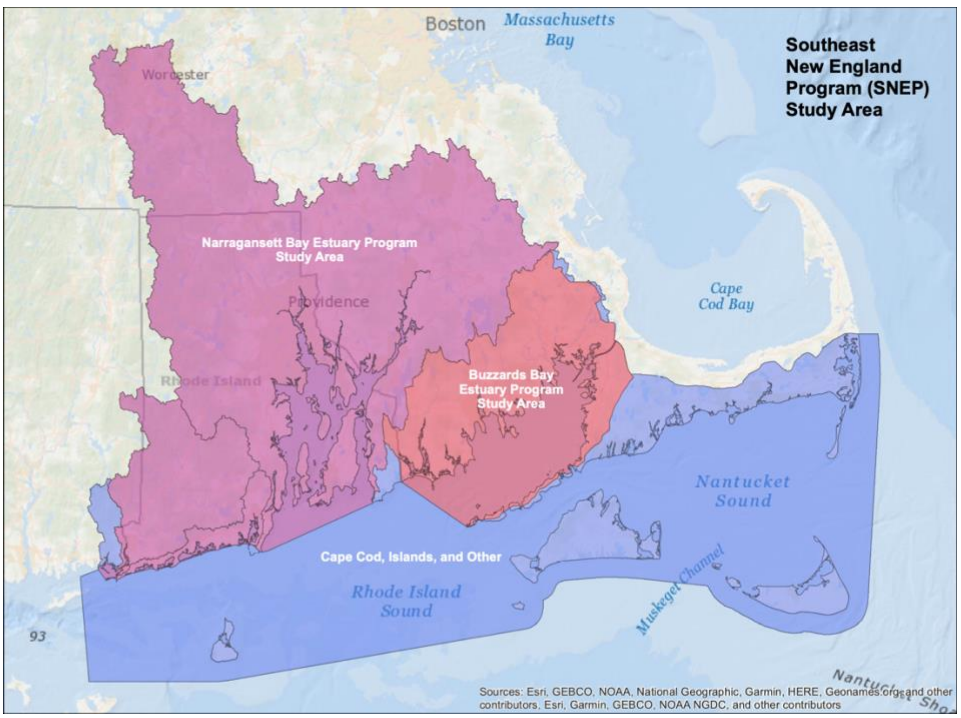
Figure A2 - 2. Screen captures of a web-based interactive concept map of interview contributors. The inset figure in the upper left-hand corner is the complete schematic and the larger figure shows the details of a singular entry point topic (Anthropocentric) and all of the contributors to that topic. When the user clicks on "Anthropocentric" the figure in the upper right-hand corner opens up and provides the user with specific information related to the topic.

Task 2C – Mapping SNEP Ecosystem Resources and Services

For this task, ecosystem resources, services, and beneficiaries were mapped and summarized within the boundaries of entire SNEP region, the Narragansett Bay Estuary Program Study Area, the Buzzards Bay Estuary Program Study Area, and for Cape Cod, the Islands, and other areas not covered by NBEP and BBEP (Figure 1).

Ecosystem resources, services, and beneficiaries for mapping were selected by SNEP staff and the GLEC team (see July 2 Meeting Summary, below). A full list of elements and data sources is provided in Table 1. Many of the sources are available as web services maintained by the source agency or entity; others were downloaded and compiled from public repositories (e.g., RIGIS and MassGIS) and analyzed in ArcGIS Desktop. All layers were then added to an interactive web map so that layers could be overlaid and viewed together.

Click here to open the IESF Viewer.



Note: EPA staff are reviewing SNEP program boundaries. Maps in this report may be updated to reflect any changes.

Figure 1. Map showing the SNEP study area and subregions for which spatial data were summarized and tabulated.

To calculate the summary statistics that follow, datasets were clipped to the SNEP region boundary and summarized by subregion. For example, total acres of eelgrass (eelgrass extent) were calculated each for the Whole SNEP Region, the Narragansett Bay Estuary Program Study Area, the Buzzards Bay Estuary Program Study Area, and for Cape Cod, the Islands, and Other.

The spatial data are prepared in such a way that summary statistics could be calculated for any other units within the SNEP region; for example, fine-scale watershed boundaries (i.e., HUC-12s) could be used to create very detailed ecological and/or demographic summaries using these data.

STUDY AREA BASIC CHARACTERISTICS

	Total land area (acres)	
Whole SNEP Region	**3,329,289.9**	
Narragansett Bay Estuary Program Study Area	2,359,794.3	70.9%
Buzzards Bay Estuary Program Study Area	500,010.2	15.0%
Cape Cod, Islands, and Other	469,485.5	14.1%

	Total water area (acres)	
Whole SNEP Region	**2,801,963.9**	
Narragansett Bay Estuary Program Study Area	241,718.3	8.6%
Buzzards Bay Estuary Program Study Area	285,842.2	10.2%
Cape Cod, Islands, and Other	2,274,403.4	81.2%

	Total shoreline length (km)	
Whole SNEP Region	**5,614.4**	
Narragansett Bay Estuary Program Study Area	2,266.8	40.4%
Buzzards Bay Estuary Program Study Area	1,319.9	23.5%
Cape Cod, Islands, and Other	2,027.8	36.1%

DEMOGRAPHICS

	Total population	Proportion female	Proportion dependent	*American Community Survey, 2014-2018; Dependent population defined as <18 and >65 years old; average of proportion across all census tracts*
Whole SNEP Region	**3,812,430**	**51.3%**	**37.8%**	
Narragansett Bay Estuary Program Study Area	2,916,815	51.1%	36.3%	
Buzzards Bay Estuary Program Study Area	476,415	51.9%	39.5%	
Cape Cod, Islands, and Other	419,200	51.6%	44.5%	

DEMOGRAPHICS

	% White	% Black	% Hispanic	% Asian	% Native American	% Hawaiian Pacific	% Two or more races
Whole SNEP Region	**79.3%**	**5.2%**	**3.9%**	**2.8%**	**0.3%**	**0.04%**	**2.3%**
Narragansett Bay Estuary Program Study Area	77.3%	5.9%	4.1%	3.3%	0.3%	0.05%	2.2%
Buzzards Bay Estuary Program Study Area	82.6%	2.5%	3.8%	1.5%	0.1%	0.02%	2.6%
Cape Cod, Islands, and Other	89.2%	2.9%	2.7%	1.3%	0.4%	0.04%	2.2%

	Proportion of population older than 5 who speaks some other language at home	*Average of proportion across all census tracts*
Whole SNEP Region	**2.5%**	
Narragansett Bay Estuary Program Study Area	3.1%	
Buzzards Bay Estuary Program Study Area	1.2%	
Cape Cod, Islands, and Other	1.5%	

	Median household income in the last 12-months	*Average of median across all census tracts*
Whole SNEP Region	**$72,271.28**	
Narragansett Bay Estuary Program Study Area	$72,725.16	
Buzzards Bay Estuary Program Study Area	$66,462.26	
Cape Cod, Islands, and Other	$75,680.73	

INDICATORS AND METRICS

	Land Cover	*NOAA Coastal Change Analysis Program (2016), 10-meter resolution*
	Impervious developed (acres)	
Whole SNEP Region	**543,912.2**	**% of total region**
Narragansett Bay Estuary Program Study Area	416,205.1	76.5%
Buzzards Bay Estuary Program Study Area	57,728.7	10.6%
Cape Cod, Islands, and Other	69,978.4	12.9%
	Upland trees (acres)	
Whole SNEP Region	**1,678,201.4**	
Narragansett Bay Estuary Program Study Area	1,227,543.0	73.1%
Buzzards Bay Estuary Program Study Area	244,655.5	14.6%
Cape Cod, Islands, and Other	206,003.0	12.3%
	Grassland, Scrub/shrub (acres)	
Whole SNEP Region	**530,249.0**	
Narragansett Bay Estuary Program Study Area	331,100.2	62.4%
Buzzards Bay Estuary Program Study Area	85,794.3	16.2%
Cape Cod, Islands, and Other	113,354.5	21.4%
	Bare land (acres)	
Whole SNEP Region	**34,972.2**	
Narragansett Bay Estuary Program Study Area	21,669.5	62.0%
Buzzards Bay Estuary Program Study Area	5,773.7	16.5%
Cape Cod, Islands, and Other	7,528.9	21.5%
	Freshwater wetland (acres)	
Whole SNEP Region	**360,324.6**	
Narragansett Bay Estuary Program Study Area	262,375.7	72.8%
Buzzards Bay Estuary Program Study Area	75,670.0	21.0%
Cape Cod, Islands, and Other	22,278.9	6.2%

INDICATORS AND METRICS

	Shoreline type (km)	*NOAA Environmental Sensitivity Index*
	Armored (km)	
Whole SNEP Region	**844.7**	**% of total region**
Narragansett Bay Estuary Program Study Area	446.2	52.8%
Buzzards Bay Estuary Program Study Area	226.8	26.9%
Cape Cod, Islands, and Other	171.7	20.3%
	Rocky and steep (km)	
Whole SNEP Region	**200.4**	
Narragansett Bay Estuary Program Study Area	107.3	53.5%
Buzzards Bay Estuary Program Study Area	12.5	6.2%
Cape Cod, Islands, and Other	80.7	40.3%
	Beach (km)	
Whole SNEP Region	**1,305.7**	
Narragansett Bay Estuary Program Study Area	315.7	24.2%
Buzzards Bay Estuary Program Study Area	265.6	20.3%
Cape Cod, Islands, and Other	724.4	55.5%
	Vegetated (km)	
Whole SNEP Region	**3,263.6**	
Narragansett Bay Estuary Program Study Area	1,397.6	42.8%
Buzzards Bay Estuary Program Study Area	815.0	25.0%
Cape Cod, Islands, and Other	1,051.0	32.2%

INDICATORS AND METRICS

Habitat

	Eelgrass (acres)	*MA (2010-2017); RI (2016)*
Whole SNEP Region	**35652.2**	**% of total region**
Narragansett Bay Estuary Program Study Area	3198.3	9.0%
Buzzards Bay Estuary Program Study Area	9196.6	25.8%
Cape Cod, Islands, and Other	23257.4	65.2%

	Saltmarsh (acres)	*MA (2005); RI (2012)*
Whole SNEP Region	**23,629.0**	
Narragansett Bay Estuary Program Study Area	5,368.2	22.7%
Buzzards Bay Estuary Program Study Area	9,235.4	39.1%
Cape Cod, Islands, and Other	9,025.5	38.2%

	Flood plain protection area (acres)	*Lands dedicated to and actively managed for the preservation of biological diversity, recreation, and cultural uses within FEMA moderate risk (0.2% annual chance or 500-year flood) flood zones*
Whole SNEP Region	**12741.6**	
Narragansett Bay Estuary Program Study Area	3864.4	30.3%
Buzzards Bay Estuary Program Study Area	0.0	0.0%
Cape Cod, Islands, and Other	8877.3	69.7%

Flooding extent

	FEMA high and moderate risk flood zones	*High risk = 1% annual chance or 100-year floodplain; Moderate risk = 0.2% annual chance or 500-year flood plain*
Whole SNEP Region	**746,889.8**	
Narragansett Bay Estuary Program Study Area	430,379.7	57.6%
Buzzards Bay Estuary Program Study Area	142,476.4	19.1%
Cape Cod, Islands, and Other	174,033.7	23.3%

	Areas susceptible to high tide flooding	*NOAA National Ocean Service Center for Operational Oceanographic Products and Services*
Whole SNEP Region	**54,928.9**	
Narragansett Bay Estuary Program Study Area	15,091.5	27.5%
Buzzards Bay Estuary Program Study Area	12,890.3	23.5%
Cape Cod, Islands, and Other	26,947.2	49.1%

INDICATORS AND METRICS

Property values		
	Zillow Home Value Index	*A smoothed, seasonally adjusted measure of the typical home value and market changes across a given region and housing type, for all single-family and condo/co-op residences, for every zip code in the region, averaged for June 2019-May 2020; average of all zip codes in each subregion*
Whole SNEP Region	$421,352.03	
Narragansett Bay Estuary Program Study Area	$361,784.94	
Buzzards Bay Estuary Program Study Area	$417,818.72	
Cape Cod, Islands, and Other	$587,142.83	

INDICATORS AND METRICS

	Shellfish closures	*MA (April 2017); RI (June 2020)*
	Approved (acres)	
Whole SNEP Region	**1,894,489.6**	**% of total region**
Narragansett Bay Estuary Program Study Area	157,502.8	8.3%
Buzzards Bay Estuary Program Study Area	258,608.8	13.7%
Cape Cod, Islands, and Other	1,478,378.0	78.0%

	Conditionally approved or Seasonal (acres)	
Whole SNEP Region	**49,172.2**	
Narragansett Bay Estuary Program Study Area	23,047.3	46.9%
Buzzards Bay Estuary Program Study Area	18,235.8	37.1%
Cape Cod, Islands, and Other	7,889.1	16.0%

	Prohibited (acres)	
Whole SNEP Region	**70,518.2**	
Narragansett Bay Estuary Program Study Area	53,936.4	76.5%
Buzzards Bay Estuary Program Study Area	9,155.9	13.0%
Cape Cod, Islands, and Other	6,310.3	8.9%

	Duration of emergency shellfish closures (event-area-days) 2018 + 2019	
Whole SNEP Region	**1877**	
Narragansett Bay Estuary Program Study Area	1643	87.5%
Buzzards Bay Estuary Program Study Area	68	3.6%
Cape Cod, Islands, and Other	166	8.8%

	Area impacted by emergency shellfish closures (acres) 2018 + 2019	
Whole SNEP Region	**2,020,040.7**	
Narragansett Bay Estuary Program Study Area	238,205.1	11.8%
Buzzards Bay Estuary Program Study Area	287,345.8	14.2%
Cape Cod, Islands, and Other	1,494,489.8	74.0%

INDICATORS AND METRICS

	Aquaculture	*MA (2013); RI (2020)*
	Total acres	
Whole SNEP Region	**3645.2**	
Narragansett Bay Estuary Program Study Area	1291.3	
Buzzards Bay Estuary Program Study Area	1028.9	
Cape Cod, Islands, and Other	1325.1	

	Oysters (acres)	*Includes multispecies aquaculture*
Whole SNEP Region	**2336.9**	
Narragansett Bay Estuary Program Study Area	960.2	
Buzzards Bay Estuary Program Study Area	1024.3	
Cape Cod, Islands, and Other	367.8	

	Clams (acres)	*Includes multispecies aquaculture*
Whole SNEP Region	**806.5**	
Narragansett Bay Estuary Program Study Area	107.9	
Buzzards Bay Estuary Program Study Area	394.7	
Cape Cod, Islands, and Other	140.8	

	Scallops (acres)	*Includes multispecies aquaculture*
Whole SNEP Region	**620.7**	
Narragansett Bay Estuary Program Study Area	164.4	
Buzzards Bay Estuary Program Study Area	453.2	
Cape Cod, Islands, and Other	0.4	

	Mussels (acres)	*Includes multispecies aquaculture*
Whole SNEP Region	**242.3**	
Narragansett Bay Estuary Program Study Area	135.6	
Buzzards Bay Estuary Program Study Area	5.5	
Cape Cod, Islands, and Other	101.2	

	Kelp (acres)	*Includes multispecies aquaculture*
Whole SNEP Region	**125.9**	
Narragansett Bay Estuary Program Study Area	184.8	
Buzzards Bay Estuary Program Study Area	0.0	
Cape Cod, Islands, and Other	48.0	

BENEFICIARIES

	County-level number of establishments in all ocean sectors, 2016	*NOAA Economics: National Ocean Watch (ENOW)*	
All SNEP Counties	**5752**	**% of total**	
MA Counties	3368	58.6%	
RI Counties	2384	41.4%	

	County-level number of establishments in living resources sector, 2016		
All SNEP Counties	**493**		
MA Counties	424	86.0%	
RI Counties	69	14.0%	**2/5 counties' data suppressed*

	…Marine construction sector, 2016		
All SNEP Counties	**56**		
MA Counties	39	69.6%	**2/6 counties' data suppressed*
RI Counties	17	30.4%	**3/5 counties' data suppressed*

	…Marine transportation sector, 2016		
All SNEP Counties	**154**		
MA Counties	121	78.6%	**1/6 county's data suppressed*
RI Counties	33	21.4%	**3/5 counties' data suppressed*

	…Offshore mineral extraction sector, 2016		
All SNEP Counties	**7**		
MA Counties	0	0.0%	**5/6 counties' data suppressed*
RI Counties	7	100.0 %	**3/5 counties' data suppressed*

	…Ship and boat building sector, 2016		
All SNEP Counties	**35**		
MA Counties	22	62.9%	**4/6 counties' data suppressed*
RI Counties	13	37.1%	**4/5 counties' data suppressed*

	…Tourism and recreation sector, 2016		
All SNEP Counties	**4863**		
MA Counties	2711	55.7%	
RI Counties	2152	44.3%	

BENEFICIARIES

	Fishing and boating access locations	*Number of locations identified in RIGIS and MassGIS*
Whole SNEP Region	**285**	**% of total region**
Narragansett Bay Estuary Program Study Area	218	76.5%
Buzzards Bay Estuary Program Study Area	17	6.0%
Cape Cod, Islands, and Other	50	17.5%

	Location affordability index	*HUD housing and transit costs as a percentage of total income, assuming median household income; averaged across all census tracts*
Whole SNEP Region	**50.2%**	
Narragansett Bay Estuary Program Study Area	50.3%	
Buzzards Bay Estuary Program Study Area	49.3%	
Cape Cod, Islands, and Other	50.2%	

ECOSYSTEM GOODS & SERVICES

	Coastal protection from salt marsh (acres)	*Acres of existing saltmarsh with high likelihood (>75% probability) of accommodating or adapting to water level increases to maintain their initial state or transition to a new non-submerged state in the 2030s*
Whole SNEP Region	**10.06**	
Narragansett Bay Estuary Program Study Area	8.51	
Buzzards Bay Estuary Program Study Area	1.54	
Cape Cod, Islands, and Other	0.00	

	Non-market value of beach visits	
Narragansett Bay Estuary Program Study Area	$24,649,261.11	*2018-2019 Upper Narragansett Bay beach aggregate value (non-market, dollars) of a beach day*
Narragansett Bay Estuary Program Study Area	1,074,742	*2018-2019 Upper Narragansett Bay beach total visits*
Narragansett Bay Estuary Program Study Area	100	*2018-2019 Upper Narragansett Bay beach total closure days*
Narragansett Bay Estuary Program Study Area	$1,064,957.47	*2018-2019 Upper Narragansett Bay beach aggregate value (non-market, dollars) lost due to beach closures*

Table 1. Ecosystem goods and services, Beneficiaries, and Indicators and Metrics with a spatial component and potential data sources.

Element from draft IESF	Definition	Category	Data source(s)
Coastal protection from salt marsh	Areas of existing saltmarsh with high likelihood (>75% probability) of accommodating or adapting to water level increases to maintain their initial state or transition to a new non-submerged state in the 2030s	Ecosystem goods and services	RIGIS, MassGIS, USGS Coastal Landscape Response to Sea-Level Rise Assessment for the Northeastern United States
Beach visitation	2018-2019 Upper Narragansett Bay beach aggregate value (non-market) of a beach day	Ecosystem goods and services	This contract; Task 5
	2018-2019 Upper Narragansett Bay beach total visits	Ecosystem goods and services	This contract; Task 5
	2018-2019 Upper Narragansett Bay beach total closure days	Ecosystem goods and services	This contract; Task 5
	2018-2019 Upper Narragansett Bay beach aggregate value (non-market) lost due to beach closures	Ecosystem goods and services	This contract; Task 5
Locations of coastal/ocean businesses and industry	County-level number of establishments in coastal and ocean sectors in 2015 (e.g., leisure and hospitality, public administration, manufacturing, marine construction, living resources, tourism and recreation, offshore mineral extraction, ship and boat building, marine transportation)	Beneficiaries	NOAA ENOW
	Locations of ports and marinas	Beneficiaries	RIGIS and MassGIS
Demographic information	Population by sex, age, median household income, race and hispanic origin, language spoken at home, 2014-2018 by census tract and age group	Beneficiaries	ESRI Living Atlas, American Community Survey
	US HUD Location affordability index	Beneficiaries	http://hudgis-hud.opendata.arcgis.com/datasets/location-affordability-index-v-3

Element from draft IESF	Definition	Category	Data source(s)
Aquaculture space	Currently operating marine aquaculture facilities based on the best available information from state aquaculture coordinators and programs. For MA, data have not been updated since 2013; RI data represent 2018 conditions.	Indicators and Metrics	www.northeastoceandata.org
Eelgrass extent	A compilation of the most recent eelgrass surveys from each state. For MA, data range in age depending on area of the state from 2010-2016. RI data represent 2016 conditions.	Indicators and Metrics	www.northeastoceandata.org
Flood plain protection area	Lands dedicated to and actively managed for the preservation of biological diversity, recreation, and cultural uses within FEMA moderate risk (0.2% annual chance or 500-year flood) flood zones	Indicators and Metrics	FEMA, USGS PAD 2.0
Flooding extent	Areas susceptible to high tide flooding	Indicators and Metrics	https://www.tidesandcurrents.noaa.gov/publications/techrpt86_PaP_of_HTFlooding.pdf
	FEMA flood zones - areas of high risk (1% annual chance or 100-year floodplain) and areas of moderate risk (0.2% annual chance or 500-year flood plain)	Indicators and Metrics	FEMA
Land cover type	10-meter resolution NOAA Coastal Change Analysis Program (C-CAP) data for RI and MA (2016). Classes include: Impervious Developed; Open Space Developed; Grassland; Upland Trees; Scrub/Shrub; Palustrine Forested Wetland; Palustrine Scrub/Shrub Wetland; Palustrine Emergent Wetland; Estuarine Forested Wetland; Estuarine Scrub/Shrub Wetland; Estuarine Emergent Wetland; Unconsolidated Shore; Bare Land; Water; Palustrine Aquatic Bed;Estuarine Aquatic Bed	Indicators and Metrics	NOAA C-CAP

Element from draft IESF	Definition	Category	Data source(s)
Property values	Zillow Home Value Index: A smoothed, seasonally adjusted measure of the typical home value and market changes across a given region and housing type, for all single-family and condo/co-op residences, for every zip code in the region, averaged for the last 12 months	Indicators and Metrics	https://www.zillow.com/research/data/
	June 2020 Shellfish Classifications for RI (Approved, Conditionally Approved, Prohibited)	Indicators and Metrics	RI DEM
	April 2017 Shellfish Clasificatinos for MA (Approved, Conditionally Approved, Restricted, Conditionally Restricted, Prohibited)	Indicators and Metrics	MA Fish & Game
Shellfish closures	Number and location of emergency closures	Indicators and Metrics	MA Fish & Game
NOAA ESIL shorelines	type of shoreline (beach, vegitated, etc). Detailed with upland and closer to the water	Ecosystem goods and services	NOAA
Saltmarsh	saltmarsh extent and type	Ecosystem goods and services	NWI
State 303d listed coastal waters	TMDL Impairments and for what reason	Indicators and Metrics	Each state DEM, DEP

Meeting Summary – Prioritizing spatial data layers for Task 2C, Mapping SNEP region ecosystem resources and services

July 2, 2020 1-2pm

Attendees: Emily Shumchenia and Chip Heil, E&C Enviroscape; Charles Goodhue, Allie Philips, Hannah Stroud, ERG; Ian Dombrowski, Bessie Wright, David Morgan, Adam Reilly, Ray Cody, Mary Jo Feuerbach, EPA Region 1; Nate Merrill, EPA ACESD

Prior to the call, Emily distributed a spreadsheet containing a list of mappable IESF elements prioritized by SNEP staff and associated datasets that could potentially be used to map them. Nate Merrill provided some additional suggestions at the bottom of the spreadsheet

The purpose of the discussion was to agree on particular indicators for demographic information and shellfish closures as well as to consider the additions made by Nate.

<u>**Outcome and immediate next steps:**</u>
The group agreed on a set of demographic indicators, shellfish closure indicators, and a subset of the additional layers to be added based on Nate's suggestions. Emily will send out a revised spreadsheet and begin building the maps.

Discussion details
Discussion focused on the following topics:

- Demographic information
    - Choose indicators also reflected in the beach visitation data
        - Age
        - Income
        - male/female
        - race/ethnicity
        - Ian - add language spoken at home
    - Adam will send qualified opportunity zones data the EPA has already compiled
    - MaryJo asked if we could include population over time. Emily will look into whether the American Community Survey archives their spatial data
- Shellfish closures
    - Emily reached out to RIDEM colleague who has a list of rain events that trigger closures (equivalent to emergency closures of MA), he will provide a list of number and location of rainfall-related closures
    - All agreed that this would be very useful contribution
    - Zones for shellfish closures are the same zones as 303d list (same polygon set); consider using these zones consistently across datasets to summarize variables like water quality, habitat etc.
    - Adam has already mapped 303d areas for RI and will share
- Additions that Nate made

- Emily thinks most of these are straightforward and can be incorporated in the scope of this task
- A few of Nate's suggestions will be incorporated by way of other IESF items already on this list (salt marsh extent and impervious surface)
- Choose a single/representative metric for now from the ORD Recreation Data; suggest "water quality perceptions"; can always incorporate more metrics later
- A few of Nate's suggestions maybe not ready yet for this scope
  - Coastal/estuary water quality – we are still accumulating program/project info for another part of this contract; maybe tackle this in the future
  - Shellfish habitat suitability – only data for MA; hold off until comparable data for RI

<u>Data that ORD will contribute</u>

1. Shellfish closures (ORD put these together for CT-ME)
2. NOAA ESIL shorelines (ORD put these together for CT-ME)
3. State 303d listed coastal waters (ORD put these together for CT-ME)
4. Beach closures (ORD has done this for BEACON beaches CT-ME)
5. ORD Recreation Survey responses

Meeting Summary – Clarifying scope and next steps for Task 2C, Mapping SNEP region ecosystem resources and services

June 9, 2020 1-2pm

Attendees: Emily Shumchenia and Chip Heil, E&C Enviroscape; Charles Goodhue, Allie Philips, Hannah Stroud, ERG; Ian Dombrowski, David Morgan, Adam Reilly, Ray Cody, Mary Jo Feuerbach, EPA Region 1; Nate Merrill, EPA ACESD

The attached document (pp. 3-8) was provided to invitees prior to the call. The document provides a description of the original deliverable and amendment as requested by EPA, the GLEC team's response to both, a list of elements from the draft Integrated Ecosystem Services Framework (IESF) that have a spatial component and could be mapped, and a list of spatial data resources that could be leveraged to address this subtask.

The purpose of the discussion was to clarify the scope of Task 2C mapping activities given the progress to-date on other tasks within the contract (e.g., the Task 2A program inventory and the Task 2B draft IESF) and ongoing or existing spatial analyses conducted by other SNEP staff or ORISE fellows.

<u>Outcome and immediate next steps:</u>
SNEP staff will comment on and rank/prioritize the IESF elements on pp. 6-7 to be included in the Task 2C mapping effort. Ian will compile all feedback from EPA and provide to Emily by Friday 6/12. The feedback will include potential datasets to use to map each element if known/preferred datasets exist. Emily will then review the priorities, suggest additional or alternative datasets as needed, and provide a final list of elements to be mapped to EPA by Friday 6/19, recognizing that the contract team may be able to add elements from the prioritized list if sufficient LOE exists in the budget.

Discussion details
Discussion focused on the following topics:

- Proposed work and deliverables. The group agreed that this work would comprise:
    - No new data development; leverage many existing datasets listed in #5 (pp 7-8)
    - Clipping/masking/extracting data in the SNEP region to create "base layers" from which SNEP and partners could conduct future analyses, i.e., this work would not combine datasets to calculate new metrics
    - Summaries of data at various scales; as an example: acres of impervious surface would be calculated and reported for the entire SNEP region, for the Narragansett Bay, Buzzards Bay, and Cape Cod watersheds, and for each HUC-12 watershed
    - Interactive ArcGIS Online map showing all of the datasets together with basic functions such as zoom in/out, turning individual layers on/off, changing the draw order of layers to examine different overlays, adjusting layer transparency.

Details about how EPA obtains ownership of the ArcGIS Online map should be discussed in the future.
  - All spatial data provided in standard geospatial formats (i.e., shapefiles, geotiffs) with metadata via DropBox or uploaded to Teams
  - A brief report would describe the data sources, compilation methods, and data summaries
- Prioritizing what to map. The group agreed that:
  - Prioritization is key because everything in the list is relevant and of interest, but the LOE does not allow for everything to be included
  - Need to consider that not all elements in #4 have data (or appropriate/complete data)
  - The team will compile the most recent delineation of each element unless EPA specifically notes that they want to map multiple years of data (e.g., land use data representing multiple decades)
  - Prioritizing beach visitations or beaches of concern could set up a nice crossover with the Task 5 beach valuation
  - Nate will share insight on coastal data that his group at ACESD has been compiling to look at drivers of coastal use/recreation
  - Priorities depend on how SNEP wants to use the map
  - Priority elements should form a solid foundation for future SNEP analyses
  - Although it would be ideal if the Subcommittees had already identified priority Indicators and Metrics from Task 2A to include in the mapping, there isn't sufficient time in this contract to wait
  - EPA can identify their "top 10" elements, concentrating on Indicators and Metrics, based on what we know already about priorities in the region (e.g., eelgrass extent is a safe bet) and then more could be added from the prioritized list if effort allows
  - EPA will add elements to the #4 list if they think priorities are missing (e.g., particular demographic data, sources that Adam and David are using in their work)
- How will SNEP use the maps?
  - Lots of possibilities, including tied directly to the IESF in the future (e.g., select a beneficiary or service in the IESF and an associated map "lights up" where those elements exist in the SNEP region)
  - Layers could be used as the basis for new indices or metrics
  - Internal to SNEP or shared publicly
  - Foundation for future ecosystem services mapping

SNEP Indicators and Metrics: Task 2C – Mapping SNEP ecosystem resources and services

1. **Deliverable requested by EPA in the PWS:**

"Characterization of SNEP ecological resources and the range of ecosystem services provided, including the region's commonalities and linkages…[The] suggested [IESF] hierarchy is predicated on the SNEP region being characterized, first and foremost, based on ecological resources, where each resource is presumed to provide one or a range of ES for the SNEP region and communities. Within each resource 'set', differentiation could be made on the ES provided by the resource. For instance, for a given large coast waterbody within that resource set, it may be possible to identify the more important ES (e.g., shell fishing, recreation, capacity for buffering effects of climate change (i.e., protection of coastal real estate), etc.). "

2. **GLEC Team Response:**

Subtask 2.C. Characterization of SNEP ecological resources and the range of ecosystem services provided, including the region's commonalities and linkages

To fully populate the IESF, and to understand the range of ecosystem services provided, ecological resources of the SNEP region must first be characterized.

This Subtask could be viewed as a first step toward the creation of ecosystem services maps throughout the SNEP region. As such, while we will work with EPA staff, SNEP Committees and Subcommittees to develop/select the preferred nomenclature and hierarchy. We also recommend considering the nomenclature and hierarchy of existing spatial datasets to ensure consistency between prior, current, and future ecosystem services maps. For example, National Land Cover Data (NLCD), state Land Use/Land Cover data, and National Wetlands Inventory (NWI) data each present spatial resource characterizations and terminologies that could be leveraged for this Subtask. The Narragansett Bay Estuary Program (NBEP) used these datasets in their 2017 State of Narragansett Bay and Its Watershed Report which not only offers methodological insights into data aggregation/hierarchies and trend interpretations that would be of value to this project but further developed these characterizations and nomenclature with respect to RI and MA environments (NBEP 2017).

Once the resources are cataloged and characterized, we will summarize similarities and differences in resource expression across the SNEP region. This element will require extensive data mining and manipulation to summarize resource information and generate summary statistics and visualizations (e.g., total acres of urban land can be calculated and compared among Narragansett Bay, Buzzards Bay, and Cape Cod areas). Zones for summarization will be determined in collaboration with EPA and SNEP Committees/Subcommittees (especially with regard to key management questions and other reporting considerations) and could build upon USGS Hydrologic Unit Code (HUC) watersheds, for example.

Table 2. Suggested land cover categories aggregated from NLCD classes, as used by the Narragansett Bay Estuary Program in their 2017 status and trends report

2016 NLCD classes	Aggregated land cover classes used by NBEP (suggested for use in Lower effort option)
Open water	Water

2016 NLCD classes	Aggregated land cover classes used by NBEP (suggested for use in Lower effort option)
Developed, open space	Urban or built-up
Developed, low intensity	
Developed, medium intensity	
Developed, high intensity	
Barren land (rocks/sand/clay)	Barren land
Deciduous forest	Forest land
Evergreen forest	
Mixed forest	
Shrub/scrub	Brushland
Grassland/herbaceous	Agricultural land
Sedge/herbaceous	
Pasture/hay	
Cultivated crops	
Woody wetlands	Wetland
Emergent herbaceous wetlands	

Higher effort (Deliverable 2C-2)

- Finer-scale state Land Cover/Land Use data, with insights from NBEP 2017 bistate crosswalk
    - MA high-resolution (1-meter) C-CAP program data (2016); 25 classes (Figure 5)
    - RI 0.5-acre Land Cover/Land Use data (2011); 37 classes which could be collapsed/cross-walked to match the MA C-CAP data (or other common set of classes) using methods similar to NBEP 2017
- Conservation Assessment and Prioritization System (CAPS) data for additional detail on natural lands, as in NBEP 2017
- NWI data for additional detail on wetland types
- Shellfish habitat and eelgrass data from www.northeastoceandata.org
- Aquaculture data from www.northeastoceandata.org

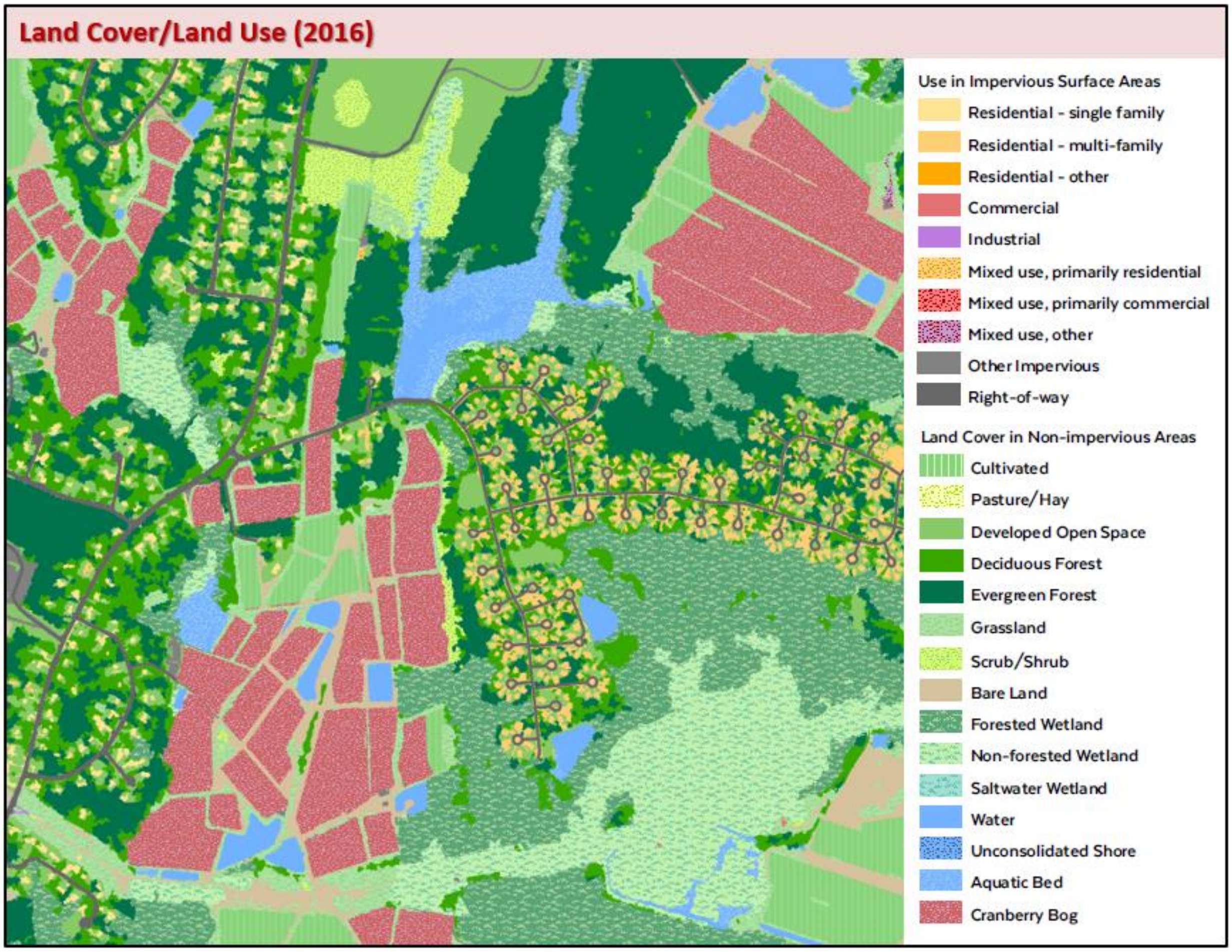


Figure 2. Example map and legend showing the 25 classes for the 2016 high-resolution Massachusetts C-CAP land cover dataset (credit: MassGIS https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use).

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3. Amendment requested by EPA:

Develop draft maps and characterizations for key SNEP resource types listed under the higher effort deliverable (2C-2), and including large estuaries, large rivers, small estuaries/embayments, tributaries to large rivers, conservation areas, and (if data are available) impervious surfaces, CSOs, stormwater and permitted discharges, and coastal/tidal barriers.

GLEC Team Response to Amendment Request:

We will modify the proposed work for this subtask so that the large ecological resource database can be manipulated and used to easily generate summary statistics of ecological resources and ecosystem services for reporting at many scales including SNEP areas, watersheds, and SNEP resources types (e.g., large estuaries, large rivers, small estuaries/embayments, etc.). We will also represent the spatial information in the form of draft maps. Because the database will be large and multivariate, we suggest developing a draft web-based and interactive map that can be visualized and queried in different ways depending on the topic of interest. For example, the map user could select the "whole SNEP region" scale and visualize summaries of ecological resources and ecosystem services profiles for the whole region. Alternatively, a user could select "large estuaries" and see summaries at that scale.

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4. Elements of the draft IESF that could be mapped

- Ecosystem goods and services
    - Animals for consumption (agricultural land?)
    - Coastal protection from beaches
    - Coastal protection from dune grass
    - Coastal protection from salt marsh
    - Habitat for species
    - Industrial water
    - Plants for consumption (agricultural land?)
    - Recreation (e.g., parks, reserves, etc.)
    - Shellfish for consumption
    - Wastewater treatment (e.g., facilities)
    - Water for consumption
- Beneficiaries
    - Locations of coastal/ocean businesses and industry
    - Residential areas
- Indicators and Metrics
    - Access to culturally significant assets
    - Aquaculture space
    - Beach volume
    - Dune extent
    - Eelgrass extent
    - Essential Fish Habitat
    - Extent of natural areas
    - Farm acreage
    - Flood plain protection area
    - Flooding extent
    - Land cover type
    - Number of ferry trips
    - Ocean industry revenue by county
    - Percent of watershed forested
    - Percent stream buffer
    - Population density
    - Presence/absence of invasive species
    - Property values
    - River miles of riparian buffer
    - Salt marsh condition
    - Salt marsh extent

- Sea level
- Shellfish closures
- Wetland area
- Wetland condition

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5. Existing compilations of spatial data in the SNEP region that relate to ecosystem resources, functions, and services to help inform the scope (green text indicates data/tools also being used or considered by David Morgan in his analyses):

- Coastal Resilience Evaluation and Siting Tool (NFWF): CREST can be used to make informed decisions about the siting of restoration and resilience projects. The tool identifies Resilience Hubs, which are areas of open space where projects may have the greatest potential to benefit both human community resilience and fish and wildlife. Resilience Hubs incorporate multiple indices, which can also be explored through CREST. See Narragansett Bay and Coastal RI Watersheds Case Study

- Resilient Land Mapping Tool (TNC): The Nature Conservancy undertook a decade long major scientific research project to map the locations of climate-resilient sites using team of scientists across the country. The results identify a resilient and connected network of sites that could sustain nature's diversity into the future.

- Resilient Coastal Sites for Conservation in the Northeast and Mid-Atlantic (TNC): Scientists from The Nature Conservancy evaluated over 10,000 coastal sites in the Northeast and Mid-Atlantic for their capacity to sustain biodiversity and natural services under increasing inundation from sea level rise. Each site received a relative resilience "score" based on the likelihood that its coastal habitats can and will migrate to adjacent lowlands under six possible scenarios of sea level rise. View storymap.

- Coastal Resilience apps (TNC, NOAA, USGS, The Natural Capital Project, others): The web mapping decision support tool includes a data-viewing platform and suite of web apps designed and tailored to meet specific planning needs, including coastal management policies, post-storm disaster decision-making, community assessments, hazard mitigation plans or cost effectiveness evaluations.

- EnviroAtlas (US EPA): 400+ datasets in four categories – Ecosystem Services and Biodiversity, Pollution Sources and Impacts, People and Built Spaces, Boundaries. See case study for New Bedford MA and surrounding area.

- Watershed Index Online (US EPA): measurements of ecological, stressor, and social characteristics compiled for roughly 83,000 small (HUC12 scale) watersheds across the conterminous United States. See library of 460 indicators for EPA Region 1.

- Estuary Data Mapper Data Inventory (US EPA): compilation of environmental data such as tidal, hydrologic, weather, water quality, and sediment quality, ground, satellite, air, and water data from EPA, NASA, NOAA, USGS-NWIS.

- Nature's Network Data & Tools (USFWS): This web-based interactive mapping tool helps identify conservation priorities, including areas of degraded habitat that, if restored, would contribute to a network of connected, intact, and resilient sites as part of the Nature's Network conservation design.
- Coastal County Snapshots (NOAA Office for Coastal Management): county-level data for every state for flood exposure, ocean jobs, and wetland benefits.
- BioMap2: Conserving the Biodiversity of Massachusetts in a Changing World (MassWildlife): designed to guide strategic biodiversity conservation in Massachusetts by focusing land protection and stewardship on the areas that are most critical for ensuring the long-term persistence of rare and other native species and their habitats, exemplary natural communities, and a diversity of ecosystems.
- Protected Area Database (USGS): America's official national inventory of U.S. terrestrial and marine protected areas that are dedicated to the preservation of biological diversity and to other natural, recreation and cultural uses, managed for these purposes through legal or other effective means.
- Restoration Potential Model Tool (MA DER): provides consistent, statewide, GIS-based indicators of ecological benefit from dam removal that can be used to help evaluate and prioritize river restoration efforts, support grant proposals, and inform communications.
- Conservation Assessment and Prioritization System (UMass Amherst): approach to prioritizing land for conservation based on the assessment of ecological integrity for various ecological communities (e.g. forest, shrub swamp, headwater stream) within an area.

Task 4A – Inventory of SNEP projects

Based on the 47 final reports uploaded by Ian, the 16 QAPPs provided by Margherita, and projects listed on the dashboard, information for 46 monitoring projects have been compiled in the spreadsheet. The objectives/goals of these projects can be summarized as follows:

- Establish baseline flow and water quality conditions for surface water, groundwater and stormwater. Plus develop Index of Biological Integrity (IBI) for surface waters.

- Identify nutrient and bacterial pollutant sources (some with GIS component)

- Evaluate conventional and innovative treatments for removing pollutants (primarily nitrogen and phosphorus), including:
  - Septic system upgrades/optimization
  - Wastewater treatment plant upgrades/optimization
  - Passive groundwater treatment (permeable reactive barrier) for nitrogen removal
  - Evaluate soil amendment to remove nitrogen from groundwater downgradient of septic systems
  - Gypsum addition to cranberry bog for phosphorus removal (did not work)
  - Carbon addition to septic system effluent to remove nitrogen (did not work)
  - Establish/increase oyster beds or ribbed mussel populations to remove nutrients (via filter feeding of plankton/seston)
  - Evaluate ability of the reed (*Phragmites australis*) to assimilate nitrogen, followed by harvesting.
  - Evaluate Best Management Practices (BMP) for nutrient removal, including green infrastructure
    - Bioretention swale
    - Rain gardens

- Outreach (education)
  - Septic system maintenance
  - Lawn care

- Effects of changing climate on watershed loading and water quality (e.g., rainfall, temperature, etc.)

When available, the duration of monitoring activities is given, as well whether or not the objectives/goals of the each project were achieved. It should be noted that only limited information is available for some of the projects. This is more prevalent for some of the newer projects (2018 and more recent) that have the least amount of information available at this stage because they were slow to get started and some are still in the QAPP development phase. Other projects in the dashboard do not indicate if they have a monitoring component.

APPENDIX

Organization(s)	Project Name	Data Collected	Indicators	Indicator descriptions	Duration of monitoring activities	Data gaps, research and assessments needs	Monitoring goal	Achieved aims	Contacts	Contact Information	Website/Reports	Final Report	QAPP	Emailed
Martha's Vineyard Shellfish Group	Annual Harvest of the Invasive Reed, *Phragmites australis* : A Potential Mitigation Strategy with Widespread Application	Phragmites: Dry weight, Height, Leaf nitrogen tissue content Groundwater: Dissolved nitrogen, Ammonia, Nitrate Pond: Temperature, Dissolved oxygen	Nutrient removal efficiency	Ability of Phragmites to assimilate nitrogen	2016-2017		Research and calculate Nitrogen uptake by Phragmites australis, a common invasive reed, and investigate annual cutting and harvesting of Phragmites as a potential Nitrogen uptake and mitigation strategy. Monitor water quality in one affected study area, and observe effects of removal on surrounding habitat, the reeds, and native vegetation. Look into value of Phragmites as a useable product in agriculture as feed stock, bedding, and compost and soil amendment. Look into value of Phragmites as biofuel source as extruded pellet fuel material, and provide training to local community on manufacturing process.		Emma Green-Beach	emma.greenbeach@gmail.com emma.greenbeach@mvshellfishgroup.or g	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf MVSG HC00A00088 Final Report.pdf	Yes	Unknown	
EPA/MassDEP/RIDEM/Horsley Witten Group/FB Environmental/Mass Conservation District/Natural Resource Conservation Service/ Town of Rehoboth, MA	Palmer River Source Tracking, Water Quality Trends Summary, and Watershed Plan	Ribonucleic acid (RNA) microarray analysis using PhyloChip Land-Use Analysis	The PhyloChip is a cutting edge analytical tool that uses specific genetic markers to determine the relative contribution to fecal contamination by different sources (i.e. human, cow, bird, etc.).		2018-2019		(1) developing recommendations for use of the PhyloChip to maximize the ability to identify fecal contamination sources with limited resources; (2) analyzing water quality trends in the Palmer River watershed using existing water quality data, geospatial information, and summary papers; and (3) assessing the impact that changing land use is expected to have in the Palmer River watershed and providing recommendations for reducing the impacts of land development on water quality		Ian Dombroski (USEPA Project Lead) Tim Bridges (USEPA Project Team) Jack Paar III (USEPA Project Team) Ray Cody (USEPA Project Team) Caitlyn Whittle (USEPA Project Team) Margherita Pryor (USEPA Project Team) Alicia Grimaldi (USEPA Project Team) Karen Simpson (USEPA SNEP Coordinator)	dombroski.ian@epa.gov bridges.tim@epa.gov paar.jack@epa.gov cody.ray@epa.gov whittle.caitlyn@epa.gov pryor.margherita@epa.gov grimaldi.alicia@epa.gov simpson.karen@epa.gov	https://www.epa.gov/snecwrp/palmer-river-source-tracking-water-quality-trends-summary-and-watershed-plan#pd			
Northern RI Conservation District	Healthy Farm, Healthy Watershed	Soil: pH; Exchangeable acidity; Modified Morgan extractable nutrients (Potassium, Calcium, Magnesium, Iron, Manganese, Zinc, Copper, Boron, Sulfur); Lead; Aluminum; Cation exchange capacity; Base saturation; Crop-specific lime and nutrient recommendations Manure: % Moisture; Total nitrogen; Ammonia nitrogen; Calcium; Potassium; Magnesium; Boron; Copper; Iron; Manganese; Sodium; Zinc	Phosphorus removal efficiency	Determine if the BMP removed phosphorus pollution (samples taken before and after)	2020-2021	In the future, the NRICD is working with their partners to plan Phase II of the Healthy Farm, Healthy Watershed Project, focused on the direct water quality impacts of the installation of BMPs (both structural and non-structural). The future phase of this project will include water quality sampling over time to determine the success of the implementation of BMPs on the levels of phosphorus in the subwatersheds in the SRW where they are installed.	Establish a manure management program for small farmers in the Scituate Reservoir watershed, reducing pollution to Providence's principal source of drinking water. Partners include the Providence Water Supply Board and University of RI.		Art Gold (University of RI) Matt Ladewig (ESS Group) Kate Sayles (Northern RI Conservation District)	agold@uri.edu (401) 874-2903 mladewig@essgroup.com (401) 330-1204 Ksayles.nricd@gmail.com (401) 934-0840 ext 3	QAPP_NRICD_v3_05012020_signed .pdf		Yes	
Association to Preserve Cape Cod/Town of Barnstable Department of Public Works (DPW)/Three Bays Preservation, Inc.	Assessment, Prioritization, Design and Installation of Stormwater Retrofits in Three Bays Watershed in Barnstable, MA	Water quality indicators; Flow; Volume reduction			2016		Strategic Collaboration and Regional Impact The four phases of this project seek to improve coastal water quality by reducing or eliminating pollutant loadings from stormwater runoff and fertilizer use through remediating high-priority stormwater outfalls that discharge directly to the Three Bays embayment. The project will conduct a detailed GIS analysis to identify potential retrofit sites for GI. Two or more of the highest rated sites will be selected for design and installation, targeting sites with runoff from 4-6 acres of impervious surface. Outreach will occur to provide public education to town residents and Town Council, including a rain garden training workshop followed by the installation of a demonstration garden. Two additional workshops will be held on site to cover operations and maintenance for the Barnstable DPW (with invitations to the rest of the Cape) focusing on the below-ground inspection, and the second for community volunteers will focus on above-ground maintenance and monitoring of vegetation, sediment buildup, and other visual indicators of performance. Pre- and post-construction water quality monitoring will be completed by Three Bays Preservation, and DPW staff will conduct stormwater sampling at installation sites. To determine the effectiveness of individual retrofits, installation will include automated samplers to measure flow and volume reduction to calculate reduction in pollutant loadings.				https://www.epa.gov/sites/production/files/2017-06/documents/fy16-snep-rfp-projects.pdf			
CT Dept. of Energy & Environmental Protection (CTDEEP)/R.I. Dept. of Environmental Management (RIDEM)/Save The Bay	Evaluation of Nutrient Loadings to the Pawcatuck River Estuary and Little Narragansett Bay	Dissolved ammonia; Whole ammonia-plus-organic nitrogen (Kjeldahl); Dissolved ammonia-plus-organic nitrogen (Kjeldahl); Dissolved nitrogen, nitrite-plus-nitrate; Dissolved nitrite; Dissolved phosphorus; Total phosphorus; Dissolved orthophosphate; Total particulate nitrogen (TPN); Total suspended solids; pH; Specific conductance; Dissolved oxygen; Water Temperature; Discharge; Chlorophyll-a; Phytoplankton; Turbidity	Water quality; Nutrient loading; Instantaneous streamflow	Calculate nutrient loads	2019-2020	The CTDEEP, the RIDEM, and the USEPA, and local town officials may use nutrient loads to develop a detailed watershed nutrient management plan for the Pawcatuck watershed.	CTDEEP will develop and apply an innovative, science-based approach to reducing nutrient pollution to Southern Rhode Island's largest watershed, in order to restore clean water, fisheries and public recreation to coastal waters shared by Rhode Island and Connecticut.		Traci Lott (CTDEEP) Heidi Travers (RIDEM) Kaitlin Laabs (USGS) Jon Morrison (USGS)	traci.iott@ct.gov heidi.travers@dem.ri.gov klaabs@usgs.gov jmorriso@usgs.gov	https://www.epa.gov/sites/production/files/2018-09/documents/snep-2018-watershed-grants-awards.pdf QAPP_PawcatuckWatershed Final April 26 2019signedqapp.pdf		Yes	
City of Cranston	Green Infrastructure at Spectacle Pond	Surface water: Water; Temperature; Dissolved oxygen; Conductivity; Flow; Total Phosphorus; Total nitrogen; Nitrate+Nitrite; Ammonia-Nitrogen; Alkalinity; Turbidity; Total iron Lake water: Water; Temperature; Dissolved oxygen; Conductivity; Secchi disk transparency; Redox potential; Total phosphorus; Total nitrogen; Nitrate+Nitrite; Ammonia-Nitrogen; Alkalinity; Turbidity; Total iron Sediment: Loosely-sorbed phosphorus; Iron-bound phosphorus, and organic matter and by UNH CFB for total phosphorus.	Assessment of watershed conditions; Review of critical resource areas; Identification of potential sediment and nutrient sources	Determine nutrient, specifically phosphorus, reduction feasibility in an impaired urban waterbody	2020	The goal of this project is to build on the approach developed for the Source Water Phosphorus Reduction Feasibility Study (2016) that was funded under a previous SNEP grant but which focused on agricultural watersheds for Newport Water surface water supplies. The data collection efforts described are needed to support this study and include direct and secondary data collection, as well as modeling.	Planning, implementation and outreach to help restore clean water to Spectacle Pond, Roger Williams Park, and the Pawtuxet River system.		Edward Tally (City of Cranston) William Guenther (Fuss & O'Neil)	etally@cranstonri.org wguenther@fando.com	QAPP_SNEP_SpectaclePond_RFA20035_signed.pdf		Yes	
EPA/Barnstable Clean Water Coalition (BCWC)	Three Bays (Massachusetts) Pilot Watershed Project	Benthic survey Groundwater nitrogen levels	Current condition (North Bay, West Bay and Cotuit Bay) Field test new low-nitrogen specific septic systems		2020 - ongoing		Determine the effectiveness of alternative technologies for removing nitrogen from Cape Cod's waters and understand which solutions will work best in the region; Assist the Cape's communities with evaluating the benefits and tradeoffs of implementing different nitrogen removal technologies.		Anne Rea (Nutrient Pilot Lead) Tim Gleason (Science Lead) Emily Smith (Communications Contact)	rea.anne@epa.gov gleason.timothy@epa.gov smith.emily@epa.gov	https://www.epa.gov/sites/production/files/2020-05/documents/cape-cod-nutrients-fs.pdf https://www.epa.gov/snecwrp/three-bays-massachusetts-pilot-watershed-project			
Town of Wareham, Wareham Water Pollution Control Facility	Process Monitoring for Optimal Nitrogen Treatment and Outfall Reduction	Headworks: pH, Biological Oxygen Demand, Chemical Oxygen Demand Anoxic tanks: Dissolved oxygen, Nitrate, Ammonium Aeration tanks: Dissolved oxygen, Nitrate, Ammonium Sand Filters and Discharge: Dissolved oxygen, Nitrogen	Headworks: warning for unusual wastewater load Anoxic tanks: fine-tune the nitrogen recycle flowrate Aeration tanks: maintain optimal oxygen levels Sand Filters and Discharge: working at optimal capacity	Plant optimization for nitrogen removal	2014-2016	Systems successfully installed; The new system allows for fine tune adjustments of oxygen levels in the anoxic process and faster reaction time. The WPCF is ultimately looking to automate these adjustments by having the probes communicate with the SCADA system, which will send a signal to manipulate the WPCF controls (valves, weirs, gates, etc.) to react to nonconforming monitoring results.	Reduce nitrogen discharges of the Wareham Water Pollution Control Facility (WPCF) through the installation of state of the art nitrogen monitoring equipment and process controls. The town installed a computerized network of monitoring probes in several critical nutrient removal processes including in the clarifiers, the effluent channel, sand filters, aeration basins, anoxic basins, secondary treatment system, and the tertiary denitrification filters. The installation of these probes and process equipment will allow for the collection and trending of data in real time, which would in turn allow immediate corrections to be made to the various treatment processes in the facility before problems arise. The new monitoring system is expected to reduce nitrogen concentrations between 0.5 and 1-ppm that will result in the reduction of up to 4,800 pounds per year when the plant is at full capacity.	Yes	Guy Campinha (Town of Wareham) Sarah Williams (Buzzards Bay National Estuary Program)	gcampinha@wareham.ma.us (508) 295-6144 sarah.williams@state.ma.us (508-291-3625	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf https://buzzardsbay.org/wp-content/uploads/2019/06/Wareham-Monitoring-System-Final-Report.pdf 01_BBNEP 2014 Town of Wareham-Monitoring-System-Final-Report.pdf	Yes	Unknown	
The Town of Westerly, RI	Implement Water Quality Improvements in Little Narragansett Bay and Lower Pawcatuck River	NO DIRECT MONITORING	Identify pollutant sources		2014/2015 - 2017 (??)	Section 5 of this report provides a summary and description of next steps for Westerly as part of the implementation plan. Table 18 provides a tabular format of the next steps and their potential for reduction in bacteria loading. VHB also developed an ArcGIS online map to present the results and recommendations of the project so that Town staff can easily access and view the information. The map presents the results of the analysis and recommendations and shows locations of pollutant hotspots, outfalls to follow up on for IDDE, areas to focus on for BMPs with potential partnerships, existing and potential locations for BMPs, and watersheds to outfalls and BMPs. This map can be updated and revised as the Town collects additional data.	The Town of Westerly is identifying, prioritizing, and implementing water quality improvements in Little Narragansett Bay and the lower portion of the Pawcatuck River. Presently, these waters have high nutrient loads, elevated bacteria levels, lower water clarity, and low dissolved oxygen concentrations. This grant will support the Town's work with Save The Bay to identify pollutant sources and develop an implementation plan to address the Phase 1 study area, which includes downtown Westerly. This plan will include recommendations for both structural and non-structural water quality improvements and an interactive map showing the results.		Nancy Letendre (City of Westerly, RI) Rui Almedia	nletendre@westerlyri.org	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf http://nbep.org/publications/NBEP-16-221.pdf	Yes	Yes	

APPENDIX

Organization(s)	Project Name	Data Collected	Indicators	Indicator descriptions	Duration of monitoring activities	Data gaps, research and assessments needs	Monitoring goal	Achieved aims	Contacts	Contact Information	Website/Reports	Final Report	QAPP	Emailed	
Buzzards Bay Action Committee	Buzzards Bay Stormwater Collaborative: A Coordinate Intermunicipal Pilot Program to Map Stormwater Networks and Monitors Discharges in Impaired Surface Waters in the Buzzards Bay Watershed	Stormwater: Surfactants, Ammonia as nitrogen, conductivity, salinity, temperature, pH, Nitrates as nitrogen, Chlorine, Enterococci, Fecal coliform, E. coli, Total Kjeldahl nitrogen, Phosphorus, Ammonia, Hydrocarbons, Total suspended solids, Color, Odor, Turbidity, Flow	Identify pollutant sources	Identify illicit connections to stormwater drains	2016-2017	Lack of rain facilitated the identification of illicit connections, of which there were few.	Map stormwater infrastructure, identify pollution sources, and gather the kinds of information necessary to prioritize action to reduce stormwater pollution and ultimately re-open shellfish beds. The results of this project will eventually lead to stormwater treatment design for priority sites. The project will seek to update the GIS database of the Buzzards Bay stormwater atlas to include connections between catch basins within catchment areas newly defined through LiDAR analysis, and pipe details and conditions not currently documented. Stormwater teams will monitor the outfalls identified, and further track and monitor those that exceed discharge limits. SmartPhone applications will assist the documentation of monitoring, and will assist in the identification and removal of illicit discharges. Water quality results will be compiled into a database meeting EPA standards, and will be publically available. It is the hope that this method will then be standardized and expanded in the future to allow for the inclusion of other municipalities to grow the baseline understanding of discharges. Finally, a cross-municipal public education program will be implemented in participating towns.	Yes	Betsy White (Buzzard Bay Action Committee)	bwhite@buzzardsbayaction.org	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf HC 2015 BBCLessons-Learned-Buzzards-Bay-Stormwater-Collaborative-6July2019.pdf	Yes	Yes		
County of Barnstable/Cape Cod Cooperative extension Marine Program	Stormwater Treatment Systems: Are They Effective in Reducing Nutrients to Coastal Waters?	Nitrogen levels	Nitrogen removal efficiency	Cost vs performance of stormwater systems	2015		The project will seek to directly compare the effectiveness of nitrogen removal in rain gardens and conventional stormwater systems on 3 Cape Cod parcels (1 each in Bourne, Dennis and Mashpee) that each contain both systems allowing for a direct comparison. Efficiency of the two systems will then be compared in terms of cost vs. performance for nitrogen removal. The results from 12 samples will be compiled into a report and shared with stormwater managers and other coastal resource decision makers in neighboring towns.		Diane Murphy	dmurphy@barnstablecounty.org	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf	Contact Bryan Dore for final project deliver ables.			
Barnstable County Department of Health and Environment/Massachusetts Alternative Septic System Test Center/University of Rhode Island/ Buzzards Bay Coalition/Hazen and Sawyer	Full Scale Assessment of Non-Proprietary Passive Nitrogen Removing Septic Systems	Nitrogen levels	Nitrogen removal efficiency	Test soil amendments to passive nitrogen removal	2016		Innovative Restoration and Protection Approaches; Strategic Collaboration and Regional Impact The project from the MASSTC seeks to demonstrate the efficacy of using a modified soil treatment area to remove up to 90% of nitrogen in a passive manner from residential septic systems. The project seeks to design and implement a non-proprietary technique for amending soil treatment options in residential septic systems. The partners will work to identify and recruit residential pilot sites, including installation and monitoring of their performance in a real-world setting. The project also seeks the development of specifications to facilitate the technique for Regional approval, allowing for other New England states to adopt the STA technique into regulations. Finally, the project will institute a management tool to relieve municipalities of the tasks of tracking the various operation and maintenance features of advanced onsite wastewater treatments systems, working to expand and adapt a tool currently in use at the MASSTC.				https://www.epa.gov/sites/production/files/2017-06/documents/fy16-snep-rfp-projects.pdf	Contact Bryan Dore for final project deliver ables.			
Martha's Vineyard Commission (MVC)/Towns of Tisbury/Town of Oak Bluffs/Umass	Permeable Reactive Barrier (PRB) for Lagoon Pond on Martha's Vineyard	Groundwater: Dissolved oxygen; Salinity; Nitrate+nitrite; Ammonium; Total dissolved nitrogen; Phosphate; Bromide; Ferrous iron; Manganese; Dissolved organic carbon; Specific conductivity; Temperature	Nutrient removal efficiency; Bromide tracer study	Ensure proper siting of the PRB; Quantify the efficacy of reducing nutrient loads with the PRB	2019-2021	1) fully evaluate the groundwater flows; 2) empirically characterize the "nitrogen plume" prior to installation; 3) comprehensively design and site/install the appropriate PRB technology based on the specific groundwater flow, vertical depth distribution of nitrogen, and nitrogen concentrations/distributions at the testing location; and lastly (4) monitor nutrient concentrations up-gradient and down gradient of the PRB to quantify PRB efficacy in reducing nutrient load to Lagoon Pond.	MVC will install and test an innovative new technology for reducing pollution from septic systems. PRBs are low-cost bioengineered systems that remove nutrients from groundwater as it flows from upland areas to coastal waters. The project will foster clean water and healthy shellfish habitat in Lagoon Pond on Martha's Vineyard, while piloting a technology with the potential to provide significant benefits throughout Southeast New England.		Adam Turner (Martha's Vineyard Commission) Brian Howes (Umass Dartmouth)	turner@mvcommission.org (508) 693-3453 bhowes@umassd.edu (508) 910-6371	https://www.epa.gov/sites/production/files/2018-09/documents/snep-2018-watershed-grants-awards.pdf MVC SNEP PRB QAPP final 2019-12-02		Yes		
Town of Jamestown	Innovative Stormwater System for Sheffield Cove	Stormwater: qPCR, Fecal coliform, Specific conductance, Dissolved oxygen, pH, temperature	Pathogen loads and producers	Determine if the BMP removed pathogen loads	2018	The grant requirements for the Sheffield Cove Innovative Stormwater and Pathogen Controls project have been completed. The Town intends to continue monitoring water quality in Sheffield Cove. The Town and RIDEM will continue to work together toward the goal of reopening Sheffield Cove to shellfishing.	Sheffield Cove was closed to shellfishing by RIDEM in 2009 as a result of bacterial exceedances found during the 2008 and 2009 routine sampling. Sheffield Cove is part of the West Passage Growing Area in Narragansett Bay. In 2015, the Stormwater Runoff & Water Quality Study of Sheffield Cove & Surrounding Watershed was completed and included 6 sampling events. The results of the sampling showed that 99% of the wet weather bacterial loads (and significant dry weather loads) originated from 2 catchments in close proximity to one another. Proposed management of the two primary sources must address both wet weather (stormwater) and dry weather (wildlife/wetlands/pet waste) sources and will include structural and non-structural approaches.	Yes	Michael Gray	mgray@jamestownri.net (401) 423-7225	http://nbep.org/publications/NBEP-16-218.pdf 26_NBEP-16-218.pdf	Yes	Yes		
Mashpee Wampanoag Tribe Natural Resources Department	Popponasset Bay Coastal Resilience and Habitat Restoration Project	Oysters: Survival, Growth Surface water: Temperature, Specific conductivity, pH, Chlorophyll, Dissolved oxygen, Salinity, Turbidity	General water quality conditions	Collect baseline water quality conditions	2016	Water quality assessment is on-going	The goal of the project would be to construct shell reef structures within Popponasset Bay and seed with oyster stock to introduce a large number of filter feeders to the bay (stated goal of 10 million over time) as a measure of water quality improvement. MWT and Mr. York will continue to measure water quality in the bar, a project already underway, using both deployed sondes and a summer water quality sampling program through the Mashpee Water Quality Collaborative.	Yes	Casey Thornbrugh (Mashpee Wampanoad Tribe) George "Chuckie" Green	casey.thornbrugh@mwtribe.com chuckie.green@mwtribe-nsn.gov	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf	Yes	Yes		
New England Interstate Water Pollution Control Commission (NEIWPCC)/RIDEM/MADEP/TetraTech Inc.	Low-Gradient Coastal Index of Biotic Integrity (IBI) for Wadeable Waters in Southern New England	Index of Biotic Integrity; water quality indicators			2018		NEIWPCC is developing a new methodology for use by Rhode Island and Massachusetts in assessing water quality, using invertebrates in the environment as an indicator of ecosystem health. The methodology will provide state agencies, municipalities and scientists with a powerful new tool for understanding pollution impacts and restoring clean coastal waters.		Tom Ardito		https://www.epa.gov/sites/production/files/2018-09/documents/snep-2018-watershed-grants-awards.pdf				
R.I. Dept. of Environmental Management (RIDEM)/University of Rhode Island/Narragansett Bay Estuarine Research Reserve/NBC/Narragansett Bay Estuary Program (NBEP)/Northeastern Regional Assn. of Coastal Ocean Observing Systems	Upgrade Monitoring of Narragansett Bay				2018		RIDEM will upgrade and replace equipment in its fixed-site monitoring network, which provides real-time water quality data on Narragansett Bay for use by environmental managers, scientists and fishermen. The project will increase the capacity of the network while improving stakeholders' access to environmental information.		Tom Ardito		https://www.epa.gov/sites/production/files/2018-09/documents/snep-2018-watershed-grants-awards.pdf				
University of Rhode Island (URI)/Coastal Carolina University/Natural Resources Conservation Service/R.I. Coastal Resources Management Council/Town of Charlestown/National Science Foundation	Estimating Groundwater Contributions to Narragansett Bay and Southern R.I. Coastal Lagoons	Flow			2018	Better understanding of groundwater flows is critical to managing coastal water quality and protecting coastal drinking water supplies.	URI will study the flow of groundwater into Narragansett Bay and Rhode Island's South Shore salt ponds.		Tom Ardito		https://www.epa.gov/sites/production/files/2018-09/documents/snep-2018-watershed-grants-awards.pdf				
EPA/USGS	Assessment of Hydrologic and Water Quality Changes in Shallow Groundwater Beneath a Coastal Neighborhood Being Converted from Septic Systems to Municipal Sewers	Groundwater: Specific conductance, Dissolved oxygen, pH, Temperature, Acid neutralizing capacity, Nitrate+Nitrite, Nitrite, Ammonium, Total phosphorus, Total nitrogen, Boron, Calcium, Chloride, Fluoride, Magnesium, Sulfate	Collect baseline water quality conditions and assess effects of new sewer system	Assess the effectiveness municipal sewers	2016-Active (on-going)	Assess the restoration of a coastal aquifer after the installation of municipal sewers that are intended to reduce nutrient loads to adjacent coastal estuaries and ponds.	Establish a monitoring network to assess groundwater levels and water quality beneath a densely developed coastal neighborhood undergoing a conversion from septic systems and cesspools to municipal sewers; and Develop an understanding of water-quality conditions before and after installation of the sewers.		Timothy McCobb Jeffrey Barbaro	tmcobb@usgs.gov (508) 490-5016 jrbarbar@usgs.gov (508) 490-5065	https://www.usgs.gov/centers/new-england-water/science/assessment-hydrologic-and-water-quality-changes-shallow?qt-science_center_objects=0#qt-science_center_objects https://www.sciencebase.gov/catalog/item/5b915c93e4b0702d0e8088b7			5/20/20	
EPA/USGS	Hydrologic Site Assessment for Passive Treatment of Groundwater Nitrogen with Permeable Reactive Barriers, Cape Cod, Massachusetts	Groundwater: Dissolved oxygen, Oxidation-reduction potential, pH, Specific conductance, Total nitrogen, Ammonia, Nitrate, Nitrite, Orthophosphate, Dissolved organic carbon, Sulfate, Chloride, Alkalinity, Boron, Dissolved iron, Dissolved manganese, Dissolved arsenic, Nitrogen isotopes	Identify potential permeable reactive barrier sites for passive treatment of groundwater nitrogen on Cape Cod, Massachusetts	Site selection and screening for PRBs	2016-2017	The effectiveness of PRBs is dependent on local conditions and site-specific hydrologic and water-quality data are needed to inform the decision to install a PRB in a given location. These data are not available in most locations on Cape Cod, and, consequently, site assessments are needed prior to selecting this treatment option. The approach provides a template for town officials and other stakeholders to follow when considering PRBs for passive treatment of nitrogen in groundwater on Cape Cod and elsewhere.	U.S. Environmental Protection Agency, U.S. Geological Survey, and Cape Cod Commission formed a technical team in 2015 to develop and evaluate a hydrologic site-assessment approach for PRB installation. The approach developed by the technical team includes a preliminary regional assessment followed by a phased on-site investigation. The approach was intended to provide the hydrologic data needed to make informed decisions on the site suitability and to support installation and monitoring should the site be deemed appropriate for a PRB. The factors that were evaluated to characterize local hydrologic conditions and inform site selection included groundwater flow directions and rates; depth to the water table; hydraulic conductivity and degree of heterogeneity of the aquifer; spatial distribution and concentration of nitrate and redox-sensitive constituents; thickness and depth of the treatment zone; distance to downgradient water bodies, and access for drilling and PRB installation.	Yes	Jeffery Barbaro Denis LeBlanc	jrbarbar@usgs.gov (508) 490-5065 dleblanc@usgs.gov (508) 490-5030	https://www.usgs.gov/centers/new-england-water/science/hydrologic-site-assessment-passive-treatment-groundwater-nitrogen?qt-science_center_objects=0#qt-science_center_objects https://pubs.er.usgs.gov/publication/sir20195047	Yes	Unknown	5/20/20	

APPENDIX

Organization(s)	Project Name	Data Collected	Indicators	Indicator descriptions	Duration of monitoring activities	Data gaps, research and assessments needs	Monitoring goal	Achieved aims	Contacts	Contact Information	Website/Reports	Final Report	QAPP	Emailed
EPA/USGS/Barnstable Clean Water Coalition	Assessment of Hydrologic Conditions in the Three Bays Watershed in Support of Nutrient Management Activities, Cape Cod, Massachusetts	Groundwater: Specific conductance, Depth, Dissolved oxygen, pH, Nitrate	Collect baseline water quality conditions for site selection of I/A septic systems	Assess the effectiveness of I/A technology after installation	2019-Active (on-going)	Although the groundwater-flow system in the watershed is generally understood from regional modeling studies, assessments of local groundwater conditions will be needed for most of the technology demonstration projects.	Conduct hydrologic monitoring and assessment in support of multifaceted nutrient-management activities in the Three Bays watershed on Cape Cod. Hydrologic monitoring will be used to evaluate the effectiveness of non-traditional technologies such as innovative and alternative (I/A) septic systems and permeable reactive barriers (PRBs) for reducing groundwater nitrogen concentrations and loads		Timothy McCobb Denis LeBlanc	tmcobb@usgs.gov (508) 490-5016 dleblanc@usgs.gov (508) 490-5030	https://www.usgs.gov/centers/new-england-water/science/assessment-hydrologic-conditions-three-bays-watershed-support?qt-science_center_objects=0#qt-science_center_objects			5/20/20
University of Massachusetts, Amherst	Gypsum as a Phosphorus and Sediment Control Agent in Cranberry Floodwaters	Cranberry bog: Total phosphorus, Total dissolved Phosphorus, Orthophosphate	Removal of phosphorus (nutrient) levels	Alum or gypsum for phosphorus removal	2015-2016	pH is a confounding factor; gypsum not an effective phosphorus control agent in freshwater ponds	Develop a management practice to control phosphorus in discharges of cranberry bog harvest floodwaters through the addition of gypsum to lower dissolved phosphorus in freshwater lakes and ponds. The project will take place on two cranberry bogs adjacent to White Island Pond, a large freshwater pond in Wareham, MA that is under a total maximum daily load (TMDL) for excessive phosphorus loads.	No	Carolyn DeMoranville (UMASS) Sarah Williams (Buzzards Bay National Estuary Program)	carolynd@umass.edu sarah.williams@state.ma.us	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf https://buzzardsbay.org/wp-content/uploads/2019/06/Neill-et-al-Cranberry-Report-Final-update-17Jan2018s.pdf 05_CZM_Final_Report_DeMoranville.pdf	Yes	Unknown	
Buzzards Bay Coalition/Marine Biological Laboratory/University of Massachusetts Cranberry Experiment Station	Reducing Nutrient Release from Cranberry Bogs	Groundwater: Particulate organic carbon, Nitrate+Nitrite, Ammonium, Dissolved organic nitrogen, Total dissolved nitrogen, Soluble reactive phosphorus, Total phosphorus Surface water: Particulate organic carbon, Particulate organic carbon, Nitrate+Nitrite, Ammonium, Dissolved organic nitrogen, Total dissolved nitrogen, Soluble reactive phosphorus, Total phosphorus Water levels	Nitrogen and phosphorus (nutrient) levels both input and output from surface and groundwater in cranberry bogs	Nutrient levels contributions from cranberry bogs	2015-2016	This study conducted the most detailed measurements made yet of surface water exchanges of nitrogen and phosphorus during cranberry bog water management and non-flood periods. It was determined that a 1-ha cranberry bog would be approximately equal to the nitrogen watershed contribution generated by one single-family home on a septic system. All bogs in the study were net sources of phosphorus to surface waters.	Study the release of nitrogen and phosphorus from cranberry bogs to better understand these nutrient loadings. Automated sampling equipment will be used to collect samples when large movements of water occur, such as during harvest flooding or following heavy rains.	Yes	Rachel Jakuba (Buzzards Bay Coalition)	jakuba@savebuzzardsbay.org	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf https://buzzardsbay.org/wp-content/uploads/2019/06/Neill-et-al-Cranberry-Report-Final-update-17Jan2018s.pdf 24_04_Neill-et-al-Cranberry-Report-Final-update-17Jan2018s	Yes	Yes	
Buzzards Bay Coalition/Town of Wareham/Town of Bourne/Town of Plymouth/Massachusetts Maritime Academy	Multi-Community Partnership to Reduce Nitrogen in Upper Buzzards Bay	Surface water: Temperature, Salinity, Dissolved oxygen, pH, Chlorophyll a, Water clarity, Dissolved Nitrate+Nitrite, Dissolved ammonium, Dissolved orthophosphate, Total dissolved nitrogen, Particulate carbon and nitrogen	General water quality conditions	Collect baseline water quality conditions	2018-2020 (varied by year and month)	An assessment was performed of the existing survey information for the railroad bed (the proposed location of the new sewer line) with the resulting recommendation that a full survey be done. The proposed monitoring program was assessed and redesigned, eliminating the proposed buoy. The grantees will attach a sonde to the MMA's bulkhead and add additional monitoring in other areas. A sewer needs analysis RFP was drafted and a hydrodynamic model RFP is in process.	Evaluate the potential of relocating the Wareham wastewater outfall and to assess community sewer needs to reduce nitrogen pollution in impaired waterbodies from on-site septic systems. The project will evaluate the feasibility of relocating the Wareham Wastewater Treatment Facility (WWTF) discharge from the Agawam River to the MMA's existing, well-flushed discharge into the Cape Cod Canal. In addition, a sewer needs analysis will be performed within the watersheds to determine how much sewering is required to meet water quality goals and to determine whether the WWTF can accommodate the higher volume. A hydrodynamic model will also be developed to understand the water quality impacts of an increased nitrogen discharge at the MMA's Taylor's Point facility.	Yes	Mark Rasmussen (Buzzards Bay Coalition) Korin Petersen (Buzzards Bay Coalition)	rasmussen@savebuzzardsbay.org petersen@savebuzzardsbay.org	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf https://buzzardsbay.org/wp-content/uploads/2019/06/Multi-community-wastewater-partnership-17-6-19-Final-Report.pdf 13_BBC Outfall Relocation BBNEP 2015 Final Report BBC_WQM_QAPP_UpperBay_Final_signed	Yes	Yes	
Buzzards Bay Coalition	Sustaining the Baywatchers Monitoring Program to Provide Critical Nitrogen Management Information in Buzzards Bay	Water quality indicators, algal pigment, ammonium, nitrite+nitrate, total dissolved nitrogen, particulate organic nitrogen, particulate organic carbon, phosphate, chlorophyll a, phaeophytin, salinity			2015	Preliminary results suggest that in January, more nitrogen occurs as highly-available inorganic forms than in March, July and August. The data collected by this project builds on the long-term monitoring, which has proven an essential tool for effective management of the Bay's resources and for educating and empowering citizens.	This project, which began in October 2015, supports Baywatchers water quality monitoring activities for 1 year, including the expansion of Baywatchers into the winter and early spring months. Baywatchers tracks nutrient-related Bay health and documents the impact of nitrogen pollution with the use of citizen scientists. For 25 years, Baywatchers has collected basic water quality, nutrient, and algal pigment information around Buzzards Bay during the summer months and educated the public on their local water quality. Baywatchers long-term monitoring has proven to be an essential tool in all regulatory aspects of coastal restoration—identifying impaired waters, evaluating discharge permits, developing TMDLs, and tracking progress towards goals.		Rachel Jakuba (Buzzards Bay Coalition)	jakuba@savebuzzardsbay.org	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf	Final report not found digitally. A hard copy may be available in the grant folder which has been archived. A digital copy may need to be obtained from the	Unknown	
Town of Charlestown, RI/University of Rhode Island/Save the Bay/Salt Ponds Coalition	Charlestown Coastal Watershed Protection and Restoration Program	Nitrogen levels			2016		Innovative Restoration and Protection Approaches; Integrating Habitat and Water Quality The Town of Charlestown will create a nutrient reduction program within the town and watershed, targeting nitrogen pollution from onsite wastewater treatment systems through quarterly sampling of up to 50 nitrogen reducing systems over three years in critical zones within the watershed. This information will help to guide and establish a funding program to upgrade 15 substandard or unpermitted older OWTS to N-reducing technology by developing a model to best predict final effluent Nitrogen concentrations, resulting in a reduction of over 150 pound of N/year. Model development will focus on using a low number of data inputs to ease the transferability and monitoring requirements for other municipalities to adopt the process. Charlestown will also develop a town-recommended landscaper process and use it to install 6 demonstration rain gardens on town properties. Two surface water sampling stations in Green Hill Pond to track nutrient impacts will be added to a current monitoring program, as it is the most heavily impacted salt pond in the town.				https://www.epa.gov/sites/production/files/2017-06/documents/fy16-snep-rfp-projects.pdf			
The University of Massachusetts-Dartmouth – School for Marine Science and Technology/Westport River Watershed Alliance/Town of Westport/Town of Westport Shellfish Department	Quantifying potential for oyster aquaculture and impacts on estuarine nitrogen related water quality: Cockeast Pond and the East Branch of the Westport River	Water quality indicators; nitrogen levels			2016		Integrating Habitat and Water Quality; Collaboration and Regional Impact; Connectivity and Ecosystem Services and Functions As communities across Southeast New England seek new approaches to lessen the impact and impairment from nitrogen enrichment, oyster aquaculture is a commonly-identified approach that is gaining momentum across the region. While the plans to use aquaculture continue to grow, there has been almost no quantification of the effectiveness of the approach. To address this gap, this proposal will analyze Cockeast Pond – a saltwater pond with a high level of nitrogen enrichment – by assessing baseline conditions from 9 years of monitoring, deploying and supporting an oyster population, and monitoring the resulting habitat and water quality, the project will assess and quantify the ability of aquaculture as a method. In a second phase, the technique would be applied to the East Branch of the Westport River to re-establish oysters reefs and further quantification of nitrogen mitigation method.		Brian Howes		https://www.epa.gov/sites/production/files/2017-06/documents/fy16-snep-rfp-projects.pdf			
Buzzards Bay Coalition (BBC)/Mass. Maritime Academy/Mass. Div. of Marine Fisheries/Town of Wareham/Town of Bourne/Town of Plymouth/Town of Marion	Multi-Community Collaboration to Reduce Nitrogen in Upper Buzzards Bay	Nitrogen levels			2018		BBC and its partners will complete engineering, environmental and fiscal studies needed to evaluate potential improvements to the Wareham wastewater treatment facility. If implemented, these improvements will lead to very substantial reductions in nitrogen pollution to Buzzards Bay, restoring estuarine ecosystems. Increased plant capacity will foster economic development by allowing towns to better address housing needs, while facilitating the growth of Mass. Maritime Academy.		Tom Ardito		https://www.epa.gov/sites/production/files/2018-09/documents/snep-2018-watershed-grants-awards.pdf signed BBC benthic.pdf		Yes, but only title page provided	
USEPA Region 1/USGS/Cape Cod Commission (CCC)/WaterVision LLC	Cape Cod Permeable Reactive Barrier (PRB) Pilot Project	Temperature; pH; dissolved oxygen; specific conductance; oxidation/reduction potential; water level; Nitrate-N; Nitrite-N; Ammonia-N; Total Kjeldahl nitrogen (TKN); Chloride; Sulfate; Total Alkalinity; Orthophosphate; dissolved organic carbon; Boron (dissolved); Iron (dissolved); Manganese (dissolved); Arsenic (dissolved)	Water quality; General chemistry; Carbon analyses; Major and minor elements		2016 (Jan.-May)		Hydrogeological Site Characterizations to Support Permeable Reactive Barrier Pilots on Cape Cod	yes	Ian Dombroski (USEPA)	dombroski.ian@epa.gov	https://www.epa.gov/snecwrp/cape-cod-permeable-reactive-barrier-prb-pilot-project			
USEPA/Town of Barnstable, MA/Town of Chatham, MA	Cape Cod Stormwater Best Management Practice (BMP) Retrofits for Control of Nitrogen	Nitrogen levels			2016-2019		Two communities were selected for direct assistance projects to design and construct stormwater best management practices (BMP) for treatment of nitrogen. Each of these communities currently has waterbodies that are impaired for nitrogen. Construction took place from April to November, 2015.		Ray Cody (USEPA) Karen Simpson (USEPA)	cody.ray@epa.gov simpson.karen@epa.gov	https://www.epa.gov/snecwrp/cape-cod-stormwater-best-management-practice-bmp-retrofits-control-nitrogen			
Rhode Island Department of Health	Building Large-Scale Capacity for the Rapid Detection of Bacterial Contamination in Coastal Waters	Bacteria levels			2015-2019	RIDOH developed a model for Oakland Beach in upper Narragansett Bay. As a next step, for this study the goal was to use the environmental data set used for Oakland Beach combined with water quality data unique to other nearby beach sites to develop models for each site.	Bacteria testing for beaches and public recreation sites, while effective, has been slow to react to high bacteria levels due to the time it takes to process water samples. Testing takes 24 hours to complete, and can mean beach closures for fecal coliform contamination take place after a threat has been present for a prolonged period of time exposing beach-goers, after a threat has passed, or keep a beach closed when the threat is no longer present. Under this funding opportunity, the BEACH program would compare the results of its traditional testing method (IDEXX Enterolert) to the EPA's method 1609 (Rapid qPCR), which allows for same-day notifications of bacterial exceedances and could potentially lower the number of closures per year. Staff would be trained in the method and the RI lab would become to the first New England-certified laboratory to use the rapid methods for water testing and notification.		Bryan Dore			Assumed yes (database says to contact Bryan Dore)	Unknown	

APPENDIX

Organization(s)	Project Name	Data Collected	Indicators	Indicator descriptions	Duration of monitoring activities	Data gaps, research and assessments needs	Monitoring goal	Achieved aims	Contacts	Contact Information	Website/Reports	Final Report	QAPP	Emailed	
Woods Hole Oceanographic Institution	Permeable Reactive Barriers	Groundwater: Nitrate+Nitrite; Ammonium; Sulfate; Dissolved iron; Dissolved manganese; Dissolved arsenic; Dissolved sodium; Methane; Conductivity; Salinity; Dissolved oxygen; Total dissolved nitrogen; Chloride; Total alkalinity; Dissolved organic carbon; pH; Temperature; Turbidity	Upgradient, within and downgradient of the PRB	Determine performance of the PRB	2020-2022	All samples that are collected will be evaluated to establish baseline conditions; nutrients, trace metals, cations/anions, total alkalinity, and dissolved organic carbon. Water level measurements will be completed to verify prior data on vertical and horizontal groundwater flow directions and rate, and pumping tests will be conducted to quantify hydraulic conductivity. Together, this information will be used to derive the nitrate mass flux at the site prior to PRB installation, and throughout the project thereafter.	Research and testing of an innovative technology to remove nitrogen pollution from groundwater.		Matthew Charette (WHOI) Kristen Rathjen (Science Wares)	mcharette@whoi.edu krathjen@sciencewares.com	WHOI_QAPP_2019_FINAL.pdf		Yes		
EPA/USGS	Assessment of Nitrogen Discharge to Cape Cod Rivers to Identify High-Priority Nitrogen Reduction Areas	Surface water: Nitrate, Nitrate flux, Flow	Identify nitrogen sources and estimate loads	Nutrient loading	2019-Active (on-going)	The objectives of the study are to design, test, and evaluate approaches for using field observations and groundwater-flow simulations to identify areas of high nitrogen loading to selected rivers on Cape Cod; investigate whether the source areas associated with the high nitrogen-loading areas can be identified for targeted nitrogen management efforts; and provide guidance to Cape Cod stakeholders on the application of study results to targeted nitrogen reduction efforts.	Measure spatial and temporal patterns of nitrogen loading in selected rivers on Cape Cod and then determine whether the measured patterns can be related to nitrogen source areas in the surrounding watersheds to prioritize nitrogen reduction efforts. Study results will improve understanding of nitrogen sources and discharge to Cape Cod rivers and provide quantitative estimates of surface-water nitrogen loads to coastal embayments.		Timothy McCobb Denis LeBlanc	tmcobb@usgs.gov (508) 490-5016 dleblanc@usgs.gov (508) 490-5030	https://www.usgs.gov/centers/new-england-water/science/assessment-nitrogen-discharge-cape-cod-rivers-identify-high?qt-science_center_objects=0#qt-science_center_objects			5/20/20	
Pleasant Bay Alliance	Regional Watershed Permit Implementation for Pleasant Bay		Water quality of Lonnie's Pond			The goals of the Lonnie's Pond demonstration have been to: (1) determine the feasibility of growing upwards of 2 million oysters; (2) determine the best approaches for aquaculture for water quality improvement; (3) initiate and evaluate outreach efforts relative to continued and expanded aquaculture efforts; (4) quantify nitrogen removals under different oyster sizes and densities; (5) determine regulatory mechanisms for continued implementation; and (6) document risks and solutions for general deployment of oysters for nitrogen mitigation in the Town's estuarine basins.	The Pleasant Bay Alliance is restoring water quality in Cape Cod's largest estuary by coordinating action among four municipalities under an integrated scientific and regulatory framework – the first such inter-municipal, watershed-based water quality permit in Southeast New England. Together, the partners are undertaking a number of actions to reduce or mitigate nitrogen pollution to Pleasant Bay, including stormwater management, shellfish restoration, and public education.		Carole Ridley (Pleasant Bay Alliance) George Heufelder (MASSTC) Ed Eichner (SMAST) Brian Howes (SMAST) Mike Giggey (Wright-Pierce)	cr@ridleyandassociates.com gheufelder@barnstablecounty.org eichner@tmdlsolutions.net bhowes@umassd.edu mike.giggey@wright-pierce.com	Pleasant Bay_QAPP_EQASig.pdf		Secondary data only Need QAPP for Lonnie's Pond		
The Ecosystem Center, Marine Biological Laboratory/Buzzards Bay National Estuary Program/Massachusetts Coastal Zone Management/Buzzards Bay Action Committee Stormwater Collaborative	Assessing climate effects on watershed and stormwater nitrogen loading and vulnerabilities in meeting TMDLs in Buzzards Bay and Cape Cod	Water quality indicators; nitrogen levels			2016		Integrating Habitat and Water Quality; Collaboration and Regional Impact; Connectivity and Ecosystem Services and Functions The proposed project seeks to better define relationships between watershed loading and estuary water quality in Buzzards Bay and Cape Cod in the face of a changing climate. Work in the Wareham River, Buttermilk Bay, and Waquoit Bay will be directed to define how water quality, namely nitrogen loading, is affected by decadal shifts in land use and climate variables. The project will evaluate how changing climate drivers (rain fall, atmosphere deposition, higher temperatures) alter the timing and amount of nitrogen discharged from watersheds into receiving estuaries. A seasonal and event-driven sampling effort will be added to ongoing efforts from the BBAC and BBC to extend the season, with the number of specific sites and their locations determined through a statistical analysis. In the three embayments, MBL will statistically evaluate water quality data to synthesize relationships between nutrient content in water columns, changes in climate-related and land cover-related variables. Models created from this analysis will account for land use and climate change, including groundwater lag time, allowing for adaptive management of TMDL's to meet resource goals. The results from these embayments will then be applied to the 23 years of data collected by the BBC to expand the range of the analysis.				https://www.epa.gov/sites/production/files/2017-06/documents/fy16-snep-rfp-projects.pdf				
EPA/USGS/Rhode Island Dept. of Environmental Management	Characterization of Water Quality in the Sakonnet River, Rhode Island	Surface water: Nitrate+Nitrite; Nitrite; Ammonia, Total dissolved nitrogen; Total particulate nitrogen; Total dissolved phosphorus; Total phosphorus; Orthophosphate phosphorus; Chlorophyll a; Suspended sediment; Specific conductance; pH; Temperature; Dissolved oxygen; Turbidity; Tide depth; Salinity; Total dissolved solids; Turbidity	Collect baseline water quality conditions	Characterize the physical and chemical conditions in the Sakonnet River	2018-Active (on-going)	The degradation of aquatic habitat and water quality in the western portions of Narragansett Bay has been and continues to be closely studied. However, there is comparably limited information available in the Sakonnet River.	1. Establish three surface water and two bottom water continuous water-quality monitoring stations in the Sakonnet River; 2. Conduct three surface water spatial mapping surveys in conjunction with vertical profiles of water quality from 16 stations		Jason Sorenson (USGS) Gevon Solomon (EPA R1) Susan Kiernan (RIDEM)	jsorenso@usgs.gov (508) 490-5022	https://www.usgs.gov/centers/new-england-water/science/characterization-water-quality-sakonnet-river-rhode-island Sakonnet QAPP.pdf		Yes	5/18/20	
Marine Biological Laboratory/Buzzards Bay Coalition/Barnstable County Department of Health and the Environment	Quantifying Nitrogen Removal by Innovative Alternative Septic Systems and Potential for Enhanced Nitrogen Removal by Labile Carbon Addition	Groundwater: Ammonium, Water flow, Nitrate, Bromide	Determine nitrate attenuation in simulated plumes	Effects of labile carbon additions on nitrate attenuation	2014/2015 - 2017 (??)	The volume and cost of the amount of carbon that would have to be added to septic effluent to induce anoxia in the vary large volumes of water in the aquifer into which septic NO-3 plumes are injected, makes carbon additions downgradient from IA or traditional Title V septic systems impractical as NO-3 removal methodology.	Quantify the nitrogen removal benefits of conversion of Title 5 septic systems to innovative alternative (I/A) systems. Quantify whether the addition of a carbon source will increase nitrogen removal in I/A systems. Compare nitrogen removal from a standard Title 5 system and two I/A systems, one of which will receive short-term addition of labile carbon designed to increase nitrogen removal.	No	Chris Neil (WHRC)	cneil@whrc.org	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf https://buzzardsbay.org/wp-content/uploads/2019/06/NEILL-Septic-Tracking-Report-Sept-2018-final.pdf 14_MBL BBNEP 2015 Final Report.pdf	Yes	Yes		
Town of Falmouth	West Falmouth Harbor Oyster Reef Development Project	Oyster: Growth, Mortality Surface water: Nitrate, Nitrite, Ammonium, Total dissolved nitrogen, Particulate organic nitrogen, Chlorophyll a, Dissolved oxygen, Temperature, Salinity, pH, Turbidity, Water depth	Nutrient removal efficiency	Determine if new oyster beds removed nutrients	2015-2017	Based on field measurements, the estimated population of oysters that were bottom planted in 2016 was approximately 308,000. For planning purposes it was assumed the mortality of an oyster bed is 50%. From these figures, the town estimated that the nitrogen uptake in shell and soft tissue for this installation was almost 50 kg per year. Some additional nitrogen may be filtered out of the water column and deposited in sediments, but this was not quantified in this study. The cost in terms of dollars per kilograms of nitrogen harvested was $272. At an estimated 50% mortality, an oyster bed covering an acre could support a population of over 2 million oysters and uptake over 350 kg N/year.	Work to reduce nitrogen loads to West Falmouth Harbor by expanding an oyster reef development project in the Snug Harbor sub-embayment. The town plans to expand the existing .25-acre reef to 1-acre by planting an additional 1,500 bags of oyster spat-on-shell, as a means to provide a biological filter for water entering West Falmouth Harbor from Mashapaquit Creek, which is a significant source of nutrients. The monitoring results of this project will inform the extent to which oyster reefs can effectively improve water quality, and can contribute to watershed management plans for West Falmouth Harbor and other similar estuaries.	Yes	Chuck Martinsen (FALDNR) Sia Karplus (Sciencewares)	FALDNR@hotmail.com sia@scierncewares.com	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf https://buzzardsbay.org/wp-content/uploads/2019/06/WF-Oyster-Bed-Final-Report-4-24-17.pdf 16_Town of Falmouth BBNEP 2015 Oyster Bed_Final Report.pdf	Yes	Unknown		
City of Newport	Source Water Phosphorus Reduction Feasibility Plan	In-lake water: Depth, Total nitrogen, Nitrate, Nitrite, Ammonia, Alkalinity, Turbidity, Total phosphorus, Temperature, pH, Conductivity, Dissolved oxygen, Secchi transparency In-lake sediment: Total phosphorus, Percent solids, Organic matter, Iron-bound phosphorus, Loosely-sorbed phosphorus Tributary: Total nitrogen, Nitrate, Nitrite, Ammonia, Total phosphorus, Total Kjeldahl nitrogen, Temperature, pH, Conductivity, Dissolved oxygen, Flow rate	Nutrient loading sources	Nutrient loading	2015	Implementation plan developed identifies a roadmap for feasible and cost-effective prioritization of efforts to reduce phosphorus loads to Watson Reservoir and St. Mary's Pond over the next several years. It is expected that these management measures will also support the achievement of goals for nutrient load reductions identified in the forthcoming TMDLs for those waterbodies. In addition to identifying nutrient reduction strategies for these two watersheds, the management measures presented in the Plan are widely applicable to addressing nutrient reduction in other watersheds within the NWD system and throughout the Narragansett Bay Estuary water	Identify and quantify sources of phosphorus to two of the nine waterbodies in the City of Newport Water Division (NWD) water supply system and to assess, recommend, and prioritize management actions to reduce contribution or "loading" of nutrients to St. Mary's Pond and Watson Reservoir. The study consisted of three phases – documentation of existing conditions in the waterbodies and watersheds, identification of management strategies to control phosphorus loading, and development of a plan to implement the recommended management strategies.		Julia Forgue (City of Newport)	jforgue@cityofnewport.com	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf http://nbep.org/publications/NBEP-14-130.pdf 07_City of Newport NBEP 2014 Final Report.pdf	Yes	Yes		
Save the Bay	Ribbed Mussel Nutrient Bio-extraction Pilot Project	Ribbed mussels: Growth rate, Survival, Growth, Nitrogen content, Filtration rate, Nitrogen absorption rate Surface water: Temperature, Salinity, Dissolved oxygen, Secchi depth, Total depth, pH	Nutrient removal efficiency	Nutrient bioextraction potential of ribbed mussels	2015	Bioextraction estimates may be useful to inform projects aimed at nitrogen mitigation of eutrophic estuarine waters using ribbed mussels.	Ribbed mussels are not commonly eaten and thus could be useful for bioextraction in polluted systems. Ribbed mussels can effectively consume nutrient-rich seston from the water column while in their natural intertidal settings or while continually submerged. This study compared growth rates of 100 adult ribbed mussels in each of three settings: (1) a fringing salt marsh, (2) hanging continually submerged in shallow water from a floating raft, and (3) in a shellfish aquaculture upweller that continually forced water past the animals to theoretically increase feeding rate.	Yes	Tom Kutcher (Save the Bay) Robbie Hudson	tkutcher@savebay.org	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf http://nbep.org/publications/NBEP-14-131.pdf 11_NBEP Save the Bay Ribbed Mussels-16-131	Yes	Unknown		
University of Rhode Island	Optimizing Performance of Existing Onsite Wastewater Treatment	Septic systems: Total nitrogen, Nitrate, Ammonium, Dissolved oxygen, pH, Temperature, Biological Oxygen Demand, Alkalinity, Average forward flow, Recirculation ratio, qPCR analysis of microbial community	Nutrient removal efficiency	Performance of nitrogen removal in advanced of OWTS	2015-2016	Results show that median total N levels in effluent are below 19 mg/L for all technologies. However, there is room for improvement. Adjusting underperforming systems can improve N removal, but not always. Adjusted systems may need longer to improve. More training of service providers may also help improve performance. The compliance rate in RI is lower than in Barnstable County, MA, where systems are monitored for total N and results are reported to a centralized database. A similar approach may improve performance in RI, keeping more N out of the Bay. URI is developing statistical models to predict total N from other parameters to help service providers. URI is also measuring the abundance of genes for enzymes that remove N to help us understand how microbes remove N in these systems.	Nitrogen in effluent from conventional OWTS (a.k.a. septic systems) enters coastal waters where it causes algal blooms that lead to poor water quality, oxygen depletion, and sometimes fish kills. URI's project goal is to optimize the performance of existing OWTS within the greater Narragansett Bay watershed to reduce nitrogen inputs. To find out how these systems are performing, URI monitored total N from advanced N-removal OWTS, identified underperforming systems so they could be adjusted, and evaluated changes in their performance. URI also evaluated methods to measure N in the field to help service providers evaluate system performance during routine visits.	Yes	Jose Amador (University of Rhode Island)	jamador@uri.edu	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf http://nbep.org/publications/NBEP-16-178.pdf 10_URI NBEP 2014 Final Report	Yes	Unknown		

APPENDIX

Organization(s)	Project Name	Data Collected	Indicators	Indicator descriptions	Duration of monitoring activities	Data gaps, research and assessments needs	Monitoring goal	Achieved aims	Contacts	Contact Information	Website/Reports	Final Report	QAPP	Emailed
Northern RI Conservation District	Moswansicut Reservoir Phosphorus Project	Surface water: Total phosphorus, Dissolved phosphorus, Total Nitrogen, Dissolved Nitrate+Nitrite	Nutrient loading sources	Nutrient loading to Moswansicut Reservoir	2015	Future educational efforts will continue to be funded in this area by Providence Water and NRICD. Recommendations include increased outreach on the topics of septic maintenance and lawn care, as well as providing funding for future years of water quality monitoring to build a 5-year dataset of tributary nutrient loading data. A toolkit of techniques used was developed to share with partner organizations.	This project sought to reduce phosphorus loading to Moswansicut Reservoir by utilizing techniques including educational mailings, workshops, community nights, and volunteer opportunities. Additionally, NRICD and partners from both Providence Water and the University of Rhode Island implemented Canada Goose management techniques at Moswansicut Reservoir and monitored phosphorus loading to the Moswansicut with a volunteer water quality monitoring program.	Yes	Gina DeMarco (Northern RI Conservation District) Molly Allard	gdemarco.nricd@gmail.com	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf http://nbep.org/publications/NBEP-14-225.pdf	Yes	Yes	
Town of Avon	Examine Stormwater Pollution to Trout Brook	Surface water: Temperature, Conductivity, Salinity, Dissolved oxygen, pH, Chlorine, Ammonia, Surfactants, Total nitrogen, Nitrate, Nitrite, Total Kjeldahl nitrogen, Total phosphorus, Total sodium, Fecal coliform, E. coli, Total suspended solids, Biological oxygen demand	Characterize stormwater run-off	Examine wet weather and dry weather inputs into Trout Brook	2017	Allowed Avon to: -Delineate stormwater catchments by building off a recent MassDEP Water Infrastructure and Technical Assistance Program grant to map and assess the condition of the Town's stormwater infrastructure, the catchments for priority outfalls that directly discharge to Trout Brook and abutting wetlands were delineated. -Survey catchment characteristics in both a desktop based and field based format and prioritize catchments for outfall sampling and BMP implementation. -Complete inspections and sampling of selected outfalls to characterize pollution. -Screen Best Management Practices (BMPs) to determine suitability of implementation in the five priority catchments. The assessment considered relative pollutant removal, relative costs, and relative permitting requirements of the BMPs to recommend short-, mid-, and long-term implementation."	Four square miles in size, Avon has over 23% impervious cover and ranks in the top 15% of Massachusetts communities in terms of impervious surface. Stormwater from these impervious surfaces flows to Trout Brook, a 604(b) listed stream in the upper reaches of Narragansett Bay. This stormwater also recharges the Town's drinking water groundwater sources. To protect its high-risk groundwater supply, address the impairment, and proactively meet NPDES permit requirements, the Town has undertaken comprehensive master planning. This project proposed to prioritize subwatershed locations for field sampling locations and to identify sites suitable in priority areas for BMPs/green infrastructure. The approach included mapping land uses, impervious surfaces, and drainage structure, and developing more detailed topography. Structures would also be inspected for condition and initial IDDE screening.	Yes	Mike Gerel		http://nbep.org/publications/NBEP-16-215.pdf 19_NBEP-16-215.pdf	Yes	Yes	
Town of Barrington, RI	Data Collection and Green Infrastructure Projects in Brickyard Pond	Waterfowl: Species, Count, Lifestage, Behavior Pond: Secchi depth, Dissolved oxygen, Temperature, Salinity, Depth, Total phosphorus, Dissolved phosphorus, Total nitrogen, Nitrate+Nitrite, Total Kjehldahl nitrogen, Aluminum, Iron, Alkalinity, Total suspended solids Sediment: Total nitrogen, Nitrate+Nitrite, Total Kjeldahl nitrogen, Total phosphorus, Aluminum, Iron, Total solids	Nutrient loading sources	Determine conditions that contribute to phosphorus accumulation in Brickyard Pond and to confirm or dismiss suspected sources of pollution	2016	This project provided the town with recommendations for structural and nonstructural BMPs including a bioretention swale, an outreach and education program for animal waste management targeted to pond abutters, and minimum elements to include in a long-term monitoring program.	The Town of Barrington is collecting water quality and sediment data and designing green infrastructure projects in and around Brickyard Pond to address water quality impairments. The Town will complete a conceptual design study for green infrastructure/stormwater best management practices for five Town-owned priority outfalls. The Town's goal is to significantly reduce phosphorus loadings to support a healthy ecology in Brickyard Pond.	Yes	Joseph Piccerelli (Town of Barrington)	jpiccerelli@barrington.ri.gov	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf http://nbep.org/publications/NBEP-16-196.pdf 22_Town of Barrington NBEP 2015 Final Report.pdf	Yes	Yes	
Clean Ocean Access/Newport, RI/Middletown, RI	Stormwater pathogens—Find it and Fix it, to Identify Pathogens at Easton's Beach	Surface water: Enterococci Sediment: Enterococci	Identify pathogen sources	Identify pathogen sources to refine proposed remediation plans	2016	The Stormwater pathogens - Find It and Fix It project collected 244 water and sediment samples in the Newport Moat, Easton's Stream and Easton's Beach during the timeframe of June 2016 to December 2016. The results indicate that very elevated bacteria levels exist in the waters of the upper Newport Moat with elevated readings into the southernmost part of Easton's Stream. The results show that bacteria are consistently present in the sediment of the upper Moat during warmer months and decreases in cooler months, very low in the sediment of Easton's Stream and a negligible amount was found at Easton's Beach.	The goal of the proposed project is focused on addressing water quality impaired by pathogens. The project will identify the likely sources of pathogens (Enterococci) that are causing water quality degradation, to develop remediation plans, and suggest improvements in the conveyance system(s) and reduce beach closures. The federal Beaches Environmental Assessment and Coastal Health (BEACH) Act requires that water from designated swimming beaches be tested for Enterococci. Extensive EPA studies have shown that Enterococci are the most efficient bacterial indicator of water quality. Enterococcus is a part of the composition of fecal coliform, which is a special kind of bacteria that is found primarily in the intestinal tracts of warm-blooded animals. These bacteria are released into the environment via human and animal feces. These pathogens can be accidentally swallowed with water. People swimming or playing in water can also be exposed to pathogens when they enter the body through small cuts, abrasions or mucus membranes.	Yes	Dave McLaughlin (Clean Ocean Access)	dave.mclaughlin@cleanoceanaccess.org	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf http://nbep.org/publications/NBEP-16-222.pdf 23_NBEP-16-222.pdf	Yes	Yes	
The City of East Providence, RI	Stormwater Mitigation Project As Sabin Point Park	Nutrient and bacteria levels	Assess effectiveness of stormwater mitigation project		2015-2017		The City of East Providence is building a stormwater mitigation project at Sabin Point Park on the Providence River to help address elevated bacterial levels. The City will partner with Brown University and the Rhode Island Department of Health staff to monitor nutrient and bacteria levels to assess the effectiveness of the project. In addition, Save The Bay will provide outreach to the surrounding communities regarding controls to stormwater runoff.		Jeanine Boyle (City of East Providence, RI)	jboyle@cityofeastprov.com	https://www.epa.gov/sites/production/files/2016-09/documents/snep-grant-summaries-fy14-fy16.pdf	No	Unknown	

Task 4.D. Report highlighting environmental and community features most valued by the public in the SNEP region

Introduction

SNEP's programmatic strategies and monitoring priorities have largely been defined by EPA staff, SNEP Committees and Subcommittees, and professional stakeholders. EPA also seeks to compile research to assess the environmental and community features and services that the public values. Characterizing the preferences and values of a broader segment of the population living, working, and vacationing in the SNEP region using traditional survey methods would be labor intensive and/or expensive and is limited to surveying ten (10) people or less because of the Paperwork Reduction Act. To address this challenge, we used a novel crowd-sourcing approach (social media data mining) to supplement SNEP programmatic knowledge with respect to the ecosystem goods and services most valued by the general public.

Social media data represents a vast quantity of information that could reveal the interests, preferences, and values of its users and avoids the limitations of other survey techniques (e.g., cost and participant restrictions). Although this area of social research is relatively new, tools to gather and analyze social media resources are readily available (Waigner et al. 2018). Social media content has been used to quantify non-use ecosystem values (Waigner et al. 2018), links between cultural ecosystem services and landscape features in Europe (Oteros-Rozas et al. 2018), and to map nature-based recreation patterns and value recreational ecosystem services related to wetlands in India (Sinclair et al. 2018). Following those examples, we used publicly available content from Twitter, one of the most widely used social media platforms, to examine the prevalence of words in SNEP region users' posts that would potentially reflect their interests and values with respect to SNEP region ecosystem goods and services.

1. Twitter Data Mining

In consultation with SNEP Staff, we selected focal words and phrases to include in searches that we felt would best capture SNEP region ecosystem goods and services that are important to the general public (Table 1). For the data mining procedure, publicly available Twitter data was accessed in accordance with the Twitter Privacy Policy. Using the agreed upon search words (Table 1), tweets from users in Rhode Island and Massachusetts were searched using the TwitteR R package. The TwitterR R package aggregated and anonymized the returned tweets so the search word prevalence could be summarized and visualized via bar charts and a word cloud (Figs. 1-3).

Table 1. Selected focal words and phrases included in Twitter searches that might best capture SNEP ecosystem goods and services of importance to the public.

Swimming	Hiking	Fishing	Ferry
Boating	Kayaking	Ocean	Beach
Wave	Wetland	Seaweed	River
Bay	Forest	Seafood	Tide
Red Tide	Nor'easter	Flooding	Drought
	Beach Closure	Seal	

The data mining procedure started March 2020 with the goal of searching Twitter once each week through July 2020. In all, we collected 20 weeks of data from March 11, 2020 through July 28, 2020 and examined ~360,000 geotagged tweets. Each time we queried Twitter, we requested the maximum number of tweets (18,000). We attempted to run queries on different days each week so as to diversify the results. We retained tweets with compound versions of the words in Table 1 (e.g., "overfishing") or place names containing the words in Table 1 (e.g., "Narragansett Bay"). There were typically under 200 (i.e., between 80 and 190) instances of the keywords in each set of results. The number of occurrences for each word for each week were calculated (***weekly word frequency***) and those weekly word frequencies were summarized for the 20 weeks of data mining (***total word frequency***) in order to best characterize the level of public importance for each word. We set up a simple webpage on GitHub to display the weekly results for review and monitoring by our internal team and SNEP Staff: https://e-c-enviroscape.github.io/snep_twitter/snep_twitter_results.html

2. Valued Ecosystem Goods and Services from Twitter

In order to represent the relative value of various SNEP ecosystem goods and services (those related to the search words in Table 1), we created a word cloud from the ***total word frequency*** (Fig. 1). The word cloud shows words or phrases from Table 1 as well as words or phrases that contain the words or phrases from Table 1. The color and size of the word relates to the number of occurrences of the word (word frequency). For example, it is clear from the word cloud that "beach" had the highest ***word frequency*** and words like "backbay" and "overfishing" had relatively lower ***word frequency***. The word cloud suggests that SNEP ecosystem goods and services of importance to the general public likely relate to 1) beaches ("beach"), the ocean ("ocean", "bay", "wave"), recreation ("fishing", "swimming", "kayaking", etc…), and commerce ("commercialfishing" and "NewBedfordfishing"). Our analysis did not attempt to determine the intent of or otherwise characterize the context of the tweets, so we are not always able to determine if these words refer to ***Cultural Services***, ***Habitat or Supporting Services***, ***Regulating Services***, or ***Provisioning Services*** as outlined in the Integrated Ecosystem Services

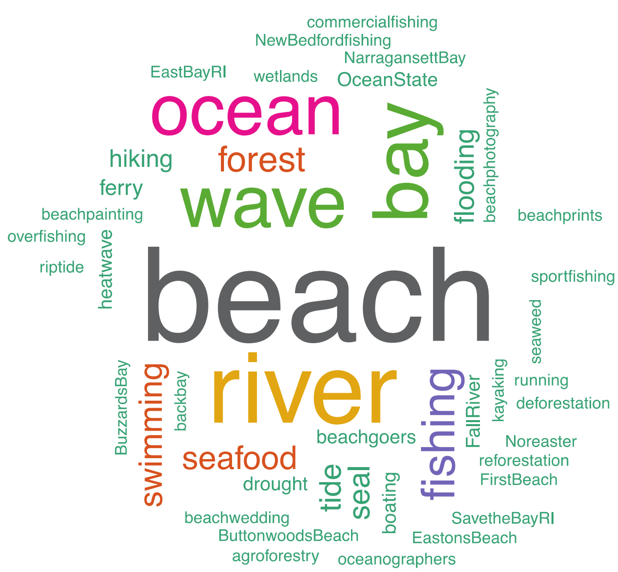

Figure 1. Word cloud representing the relative value of various SNEP ecosystem goods and services (those related to the search words in Table 1).

Framework (IESF, see Subtask 2.B report). However, some compound words, such as "beachpainting", do convey a particular ecosystem service (in this case, recreation, a Cultural Service).

To get a sense of the frequency in which the SNEP keywords were found in tweets from March through July 2020, we plotted the total counts for the top ten (10) keywords (Fig. 2). The bar graph in Figure 2 presents a qualitative representation of the keyword twitter mentions. For example, the word cloud illustrates that 'beach" is the most used word, but the bar graph shows that it was mentioned 455 times during that period, 141 times more than the next closest word ("river" at 314 mentions).

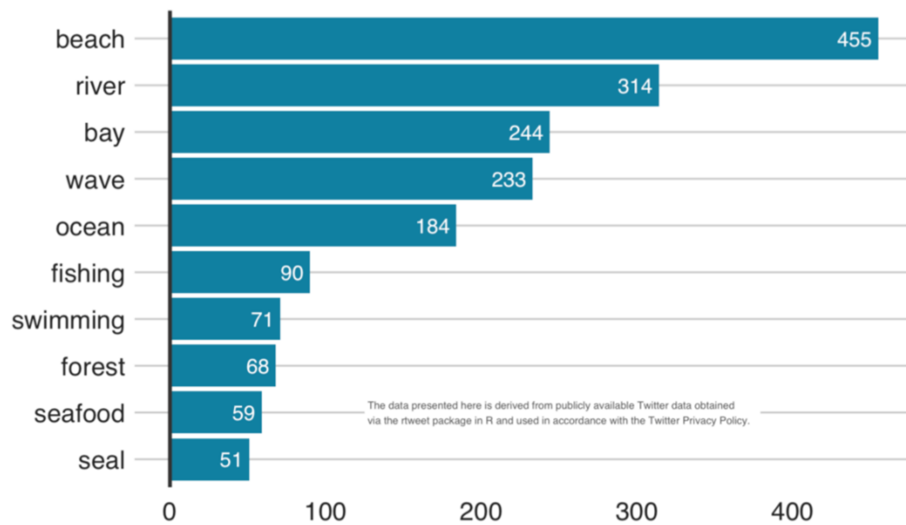

Figure 3. Number of times the top ten (10) SNEP keywords were used in tweets from March – July 2020.

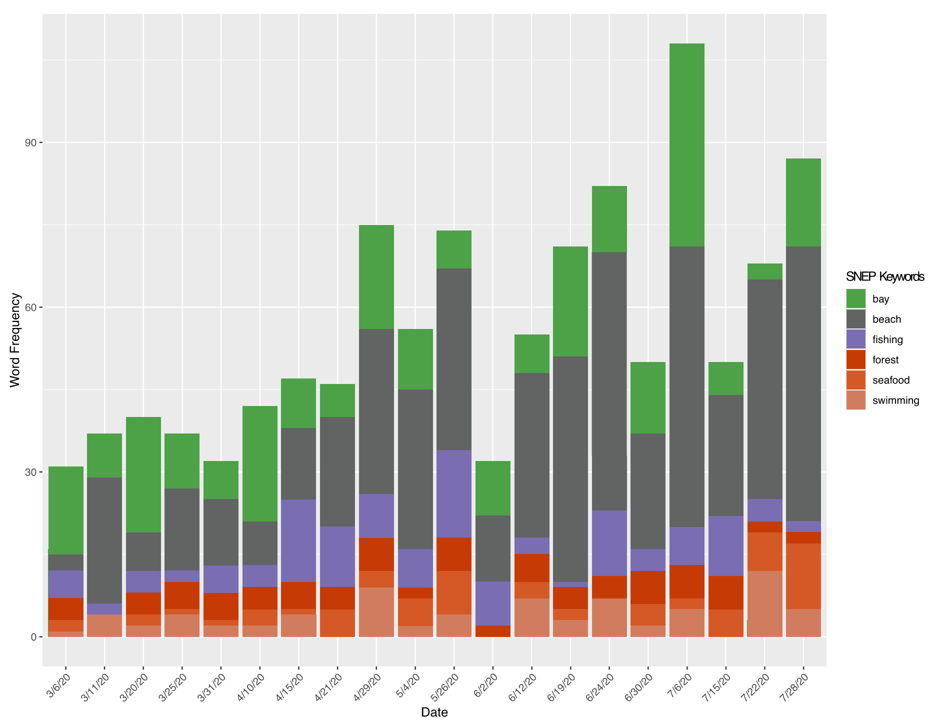

Figure 2. Occurrence of five (5) of the top SNEP keywords for each search date.

To better understand how the keyword use changed overtime, we plotted five (5) of the top ten (10) words shown in Figure 2 for each of the search dates (Fig. 3). As in the previous figures, the word "beach" is often the most frequently used word overall, but we see that it was not always the most commonly used word. For instance, in March and April, "bay" was more frequently used in three (3) out of the nine (9) searches. Trends in other keywords are relatively consistent throughout the search dates (e.g., "forest" and "seafood"). We can also see that the total number of tweets containing SNEP keywords increased from late winter and spring months to the summer months, perhaps corresponding in an increase in use of ecosystem services in the region with improving outdoor weather.

3. Social Media Content Data Mining - Comments

This task was an exploratory exercise in data mining publicly available social media content to determine public interest in SNEP region ecosystem goods and services. This relatively new approach allows gathering large quantities of data in a rapid and cost-effective manner.

The results of this task provide insight into ecosystem goods and services that are valued by the general public. Although the data provide a qualitative assessment of the usage of specific SNEP keywords, without being able to establish the intent of the use it is not possible to determine the specific IESF ***Ecosystem Goods and Services (ESV)*** category(ies) of the word (or the social media post itself). For instance, does the occurrence of the word "fishing" refer to a recreational activity (***Cultural Service***) or a resource acquisition activity (***Provisioning Service***)? Maybe just knowing that "fishing" is important to the general public is sufficient information needed to assist in the decision-making process.

The data mining approach outlined in this report was intended to demonstrate the concept of accessing and analyzing social media content to address the challenges associated with characterizing the preferences and values of a broader segment of the population in the SNEP region. Our demonstration only used social media content from Twitter, but the same approach could be used for other social media platforms as well. Collecting data from multiple platforms would likely provide a more representative view of public preferences and values since user demographics (e.g., age) vary depending on the platform. In addition, the geographic constraints used in our example were very broad (only searched geotagged tweets from RI and MA; geotagging is a feature that the user must elect to turn "on"). Since we were limited to searching 18,000 tweets per search, the searches might have been more representative of the SNEP region if the geographic extents were more strictly defined to SNEP counties, for example. This type of hyper-targeted query was not possible with the TwitteR R package that we used for this study.

There are more sophisticated techniques for both collecting and analyzing social media posts (e.g., Jeong et al., 2019; Hedayatifar et al., 2020), including sentiment analysis (Jeong et al., 2019), that could address some of the limitations outlined above. Considering the relatively low effort required to mine the 360,000 tweets for this task and provide a webpage to view the data as it was collected, it is possible that data could be continually collected and analyzed at least at a cursory level using our current techniques and at a detailed level with some additional analytical modifications/techniques.

The data used in this approach were publicly available and free. If users did not make their account public or geotag their tweets, their tweets were not included in the search. There are also inherent demographic biases with respect to people's access to social media and the manner in which they use social media that surely impact the results.

Finally, it is necessary to acknowledge that the unusual social circumstances associated with the COVID-19 pandemic were sure to have influenced people's social media posts during the entire period of our analysis, particularly March through June when large proportions of the population in the SNEP region were self-quarantining or drastically limiting activities outside of their homes. A similar analysis in a non-pandemic year might provide the contrast needed to gain some insight into the social and emotional importance of open spaces and recreation during a time of confinement and restricted social interactions.

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Task 5. Ecosystem Service (ES) Valuation of SNEP Ecosystem Resources/Functions (EF/R) – A First Step

Introduction

The objective of this task is to conduct a preliminary Ecosystem Services (ES) valuation of a targeted SNEP region estuary-related ecosystem service or good that is subject to regular monitoring and would have a direct response to best management practices. This report details a beach day valuation for 15[1] individual or clusters of SNEP region beaches that have a history of closures due to high bacterial counts to determine the non-market value lost due to those closures. A better understanding of that value can provide further justification for continued funding of monitoring programs and/or the initiation/continuation of management actions.

1. Ecosystem Good or Service Valuation

To best identify an appropriate estuary-related ecosystem service or good for the valuation, E. Shumchenia and C. Heil first met with EPA ORD task advisors N. Merrill and M. Mazzotta at the EPA Narragansett office on January 7, 2020 to become familiarized with ORD projects and objectives related to ES valuation in the SNEP region. This meeting was the first of four (4) expected meetings in completion of the task and provided the opportunity to discuss practical limitations for the valuation exercise. Advisors Merrill and Mazzotta shared reports, documents, and spreadsheets that relate to completed and ongoing work on ES valuation. In the weeks following that meeting, additional reports and documents from SNEP Subcommittee members regarding other completed and ongoing ES valuation research projects by Mass Audubon and the Cape Cod Commission were provided to the contract team.

Based on the meeting discussion and a review of the materials provided by ORD staff and SNEP Subcommittee members, it was decided that the preliminary valuation would be:

"A Beach Day Valuation to Determine the Non-Market Value Lost Due to Beach Closures"

The "non-market value" refers to the dollar amount an individual would be willing to pay for a beach day (hereafter referred to as "willingness to pay" or WTP) beyond the market value they already pay for a beach day (i.e., transportation costs, parking fees, etc.). The premise of this valuation is that beach closures have been or can be mitigated by management policies/actions in the SNEP region. For each of these management policies/actions, there are direct costs and benefits, i.e., mitigation money spent results in decreased beach value (societal) loss. By quantifying the aggregate WTP value lost due to beach closures, SNEP region stakeholders (particularly funding agencies) are provided with an economic justification for new, continued, and/or increased funding to support monitoring and management activities.

This valuation exercise is an extension of the work of S. Lyon and EPA ORD task advisors and staff N. Merrill, K. Mulvaney, and M. Mazzotta (*Valuing Coastal Beaches and Closures Using Benefit Transfer: An Application to Barnstable, Massachusetts,* 2018) in which they present "*a benefit transfer approach to estimating the economic value of public beaches and the lost value due to beach closures*". Although their methods and models are specific to beaches in Barnstable, MA (an area of Cape Cod within the

[1] 19 total beaches were considered in the evaluation, but some beaches were considered as a cluster due to limitations of cellular data location accuracy. For example, Scarborough State Beach North and South were considered as a single beach cluster.

SNEP region), they are transferrable to other locations. Lyon et al. note that benefit transfer valuations are often inappropriate or limited because study results are related to site-specific conditions and changes that are not universally relevant or equitable. These issues can be minimized by geographically restricting the benefit transfer to locations nearby (i.e., within the SNEP region).

2. SNEP Region Beaches

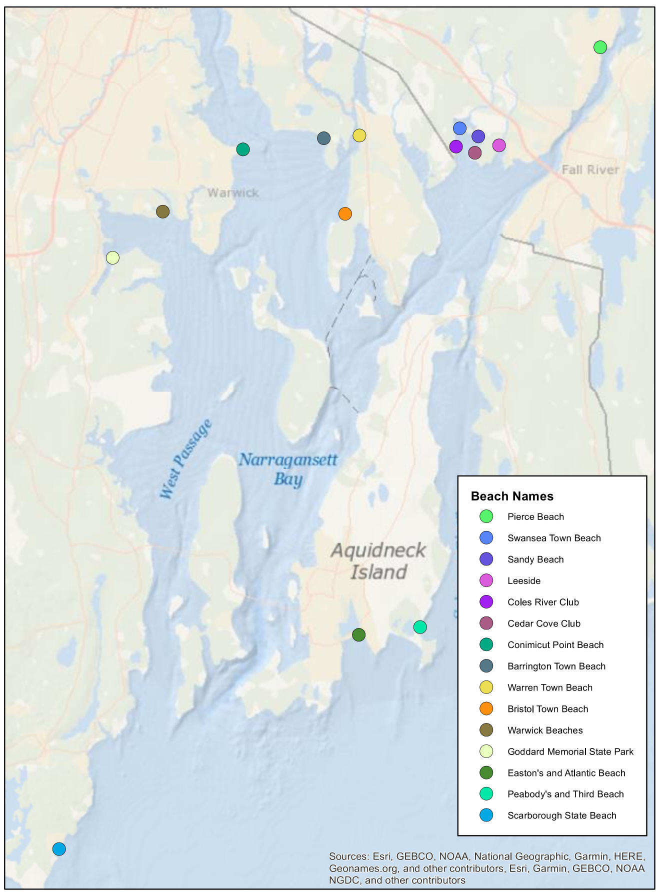
In order to demonstrate the potential usefulness of the valuation exercise, it was necessary to select beaches that had a history of beach closures. SNEP staff and ORD advisors suggested several beaches in the upper portion of Narragansett Bay because of their proximity to communities of concern and the most severe water quality impacts as well as recent improvements (e.g., Bristol Town Beach, Warren Town Beach, Barrington Town Beach, Oakland Beach in Warwick, Somerset Town Beach, and Mount Hope Bay beaches). To gather more information regarding the status and trends of beaches in Narragansett Bay and Mount Hope Bay, we referred to the "Marine Beaches" chapter of the State of Narragansett Bay and Its Watershed 2017 Technical Report (*Narragansett Bay Estuary Program*, 2017). That report characterized the marine beaches of Narragansett Bay into "High Concern" and "Low Concern" beaches based on their number of closure events per year; beaches with greater than 1.5 mean closure events per year are considered "High Concern" beaches while beaches with less than 1.5 mean closure evens per year are considered "Low Concern" beaches (p. 433; *Narragansett Bay Estuary Program*, 2017). The report clusters beaches into five (5) groups by their position in the Bay; Upper Estuary, Sakonnet River, Mouth of the Bay, East Passage, and West Passage. Only the Upper Bay, Sakonnet River, and Mouth of the Bay have beaches that are categorized as "High Concern" and of those beaches, Upper Bay beaches account for the highest percentage of closures. We chose to include all "High Concern" beaches (Table 1) as well as Upper Estuary "Low Concern" beaches in order to include beaches from Mount Hope Bay/Massachusetts (Table 1 and Figure 1).

Table 1. Selected SNEP region beaches included in the valuation exercise. "Beach ID" is the beach identification number on EPA's BEACON 2.0 – Beach Advisory and Closing on-line Notification website. "Concern Level" and "Bay Region" are taken from Narragansett Bay Estuary Program (2017).

Beach Name	Beach ID	Concern Level	Bay Region
Barrington Town Beach	RI245197	High	Upper Estuary
Bristol Town Beach	RI627966	High	Upper Estuary
Warren Town Beach	RI397836	High	Upper Estuary
City Park Beach	RI596700	High	Upper Estuary
Conimicut Point Beach	RI162580	High	Upper Estuary
Goddard Memorial State Park	RI810609	High	Upper Estuary
Oakland Beach	RI327519	High	Upper Estuary
Atlantic Beach Club	RI673854	High	Mouth of the Bay
Easton's Point Beach	RI381265	High	Mouth of the Bay
Peabody's Beach	RI276487	High	Sakonnet River
Third Beach	RI840021	High	Sakonnet River
Scarborough State Beach - North	RI606484	High	Mouth of the Bay
Scarborough State Beach - South	RI606485	High	Mouth of the Bay
Pierce Beach	MA430398	High	Upper Estuary

Table 1 (continued). Selected SNEP region beaches included in the valuation exercise. "Beach ID" is the beach identification number on [EPA's BEACON 2.0 – Beach Advisory and Closing on-line Notification website](). "Concern Level" and "Bay Region" are taken from Narragansett Bay Estuary Program (2017).

Beach Name	Beach ID	Concern Level	Bay Region
Cedar Cove Club	MA913781	Low	Upper Estuary
Coles River Club	MA372082	Low	Upper Estuary
Leeside	MA498031	Low	Upper Estuary
Sandy Beach	MA536859	Low	Upper Estuary
Swansea Town Beach	MA249263	Low	Upper Estuary



3. Determining Beach Value by Benefit Transfer

To accomplish the pilot valuation of select SNEP region beaches and the ecosystem services (ES) they provide, we used the ***Benefit Transfer*** method (Ready and Navrud, 2003; Iovanna and Griffiths, 2006; Wilson and Hoehn, 2006; Johnston et al., 2015; Richardson et al., 2015). Simply, the benefit transfer method refers to the process of transferring economic values from one situation to another. In this case, it can be used to estimate economic values for a SNEP region ES by transferring ES valuations from other locations with similar ES. The beach valuation outlined in this report follows the methods of Lyon et al. (2018) (shown schematically below Figure 2) The 2-step procedure involves:

1. Determining the ***Consumer Surplus*** value, or Willingness to Pay (WTP), that considers several parameters including beach characteristics (location, saltwater vs freshwater, and beach length), beach closure history, and residents versus non-residents use. ***Consumer Surplus*** is a measure of non-market value and reflects the societal benefit received above and beyond out-of-pocket expenditures already incurred to enjoy the ES (i.e., transportation costs and parking fees for a beach day).
2. Estimating the ***Number of People (Visits)*** using a ***Visitation Model*** based on cellular device location-based datasets (cell data) and accounts for weather conditions, time of year, and parking availability.

As illustrated in Figure 1, the ***Value of a Beach Day*** (in $/beach day) will be calculated for each beach by multiplying the ***Consumer Surplus*** by the ***Visits***.

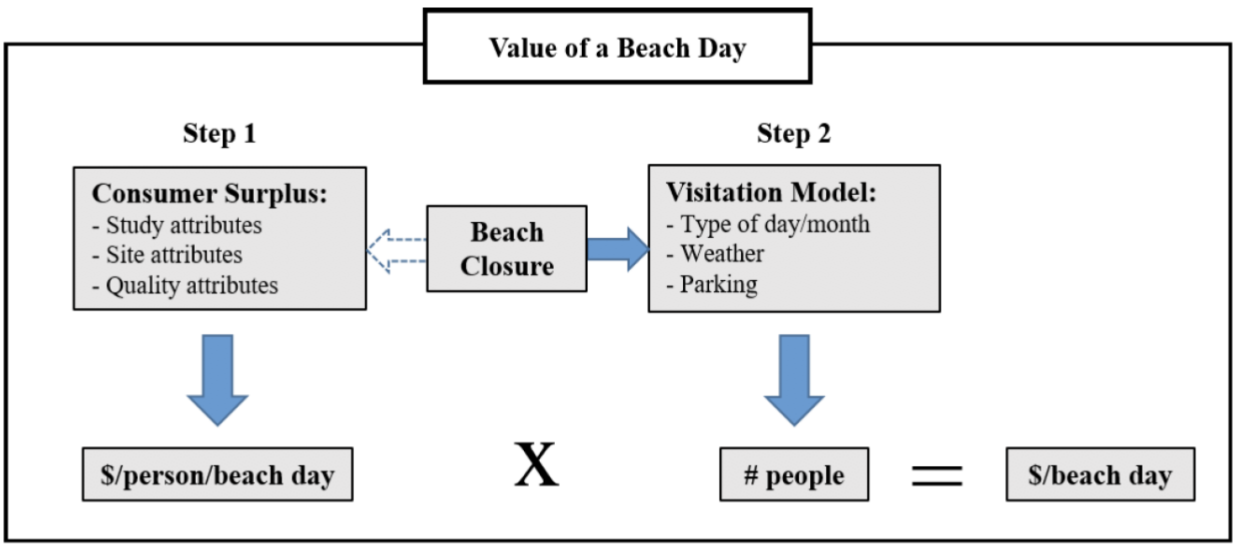


Figure 2. Schematic showing the 2-Step process to estimate the value of a beach day. (from Lyon et al., 2018)

Step 1: Consumer Surplus Estimation

In order to estimate the ***Consumer Surplus*** for the selected SNEP region beaches, we used the regression model of Lyon et al. (2018). A detailed description of the model and its development can be found in Lyon et al. (2018). The model is based the benefit transfer of consumer surplus values from 25 studies of beach use and swimming. We used the "Meta_analysis.R" script of Lyon et al. (2018) (https://github.com/USEPA/Recreation_Benefits) to calculate the ***Consumer Surplus*** for each beach. (The EPA ORD advisors for this task developed an Excel spreadsheet for a more user-friendly Consumer Surplus estimator "WTP tool
for beaches.xlsx").

The necessary input parameters for the model include beach characteristics (regional location, saltwater vs freshwater, and beach length), beach closure history, and visitation characteristics (daily visits versus overnight, residents vs. non-residents, and % fewer people during beach closures). The beach characteristics (location, saltwater versus freshwater, and beach length) and beach closure history were obtained from EPA's BEACON 2.0 – Beach Advisory and Closing on-line Notification website. For "residents versus non-residents" and "% fewer people during beach closure" we used the same values reported by Lyon et al. (2018): 49% resident visitors and 67% fewer people during closures, for simplicity. In addition, since the visitation model used daily cell phone records, we assumed all visits to be "daily". Table 2 summarizes the beach and visitation characteristics used to calculate the ***Consumer Surplus*** for each beach.

Table 2. Beach characteristics used to calculate the Consumer Surplus for selected SNEP beaches.

Beach Name	Beach Length	Water Type	Monitored	Consumer Surplus (CS)	CS Lower Limit	CS Upper Limit
Barrington Town Beach	0.21	Salt	Yes	$22.97	$8.23	$64.09
Bristol Town Beach	0.17	Salt	Yes	$22.98	$8.24	$64.11
Warren Town Beach	0.05	Salt	Yes	$23.00	$8.24	$64.17
City Park Beach	0.3	Salt	Yes	$22.96	$8.23	$64.04
Conimicut Point Beach	0.178	Salt	Yes	$22.98	$8.24	$64.10
Goddard Memorial State Park	1.06	Salt	Yes	$22.82	$8.18	$63.65
Oakland Beach	0.27	Salt	Yes	$22.96	$8.23	$64.06
Atlantic Beach Club	0.22	Salt	Yes	$22.97	$8.23	$64.08
Easton's Point Beach	0.671	Salt	Yes	$22.89	$8.21	$63.85
Peabody's Beach	0.157	Salt	Yes	$22.98	$8.24	$64.12
Third Beach	0.8	Salt	Yes	$22.87	$8.20	$63.79
Scarborough State Beach North	0.61	Salt	Yes	$22.90	$8.21	$63.88
Scarborough State Beach South	0.27	Salt	Yes	$22.96	$8.23	$64.06
Pierce Beach	0.195	Salt	Yes	$22.97	$8.23	$64.10
Cedar Cove Club	0.04	Salt	Yes	$23.00	$8.24	$64.18
Coles River Club	0.034	Salt	Yes	$23.00	$8.24	$64.18
Leeside	0.07	Salt	Yes	$23.00	$8.24	$64.16
Sandy Beach	0.154	Salt	Yes	$22.98	$8.24	$64.12
Swansea Town Beach	0.041	Salt	Yes	$23.00	$8.24	$64.18
			Average Values	$22.96	$8.23	$64.05

At the scale for which the model's benefit transfer is appropriate for the selected SNEP region beaches, all beach and visitation characteristics were held constant except for beach length. It is evident from our results (Table 2) and those of Lyon et al. (2018) that beach length has a very slight negative impact on the ***Consumer Surplus*** for each beach (i.e., longer beaches have a slightly lower ***Consumer Surplus*** value). The modelled ***Consumer Surplus*** values (in 2016$) for the selected SNEP beaches range from $22.82 to $23.00 with the lower and upper bounds of a 68% prediction interval of $8.18 and $64.18, respectively. Although there is a significant degree of uncertainty associated with these estimates, the ***Consumer Surplus*** value for these SNEP beaches is generally consistent with the $21.99 ***Consumer Surplus*** value estimated by Lyon et al. (2018) for other SNEP beaches in Barnstable, MA.

Step 2: Visitation Model

The visitation data was provided to the contract team by the EPA ORD advisors, Merrill and Mazzotta. "Corrected visits" were provided to the contract team for each beach for each day for the months of

June, July, August, and September for 2018 and 2019. A detailed description of the visitation model can be found in Merrill et al. (2020), but a general description is necessary to understand the inherent complications and associated errors.

The model uses commercially available anonymized and aggregated data on cellular device locations (cell data) to estimate visitation to natural areas like the beaches of concern in this report. In addition, the data can be used to determine the origin of the visitors at the census block level. The cell data was calibrated using observational counts from commonly recorded sources of park and beach visitations in order to more accurately reproduce daily visits. Using the calibrated cell data, a visitation model was developed to predict daily visits for recreational areas that takes into account weather, month, day of the week, and size of water access.

For the purposes of this task, we used the calibrated, or "corrected", daily ***Visits*** determined from the cell data. As noted above, the cell data was converted to daily corrected visits for June, July, August, and September for 2018 and 2019 for each beach, however, because of the close proximity of some beaches used in this valuation, the cell data was not able to accurately distinguish the visit location and the beaches had to be grouped. For instance, cell data locations from Scarborough Sate Beach North and Scarborough State Beach South, located in the Mouth of the Bay in Narragansett, RI (Fig. 1), are indistinguishable from one another, so they were grouped. The same was true for Easton's Beach and Atlantic Beach Club in Newport, RI, Peabody's Beach and Third Beach in Middletown, RI, and City Park Beach, Oakland Beach, and Buttonwoods Beach in Warwick, RI (Fig. 1). For simplicity, City Park Beach, Oakland Beach, and Buttonwoods Beach will be referred to collectively as "Warwick Beaches".

Value of a Beach Day

The ***Value of a Beach Day*** ($/beach day) was calculated for each beach by multiplying the ***Consumer Surplus*** value (2016$/person/day) by the ***Visits*** (#people). These daily ***Value of a Beach Day*** numbers were summed for 2018 and 2019 for each beach or group of beaches (Tables 3 and 4). Total Visits and Total Value categories should be interpreted in the context of the "*Percent of Days with Data*" since some beaches were lacking cell data on certain days, which resulted in an artificially lower estimated **Total Value of a Beach Season** (most notably Cedar Cove Club, Coles River Club, and Barrington Town Beach). Conversely, the beach closure data is considered to be accurate and complete for all beaches.

Table 3. 2018 Visitation, Closure, and Aggregate Value Data. Totals values represent 122 total days over the beach season (June, July, August, September).

Beach Name	% of Days with Data	Total Closure Days	Total Visits	Total Value of Beach Season	Total Value Lost Due to Closures
Scarborough State Beach	97.54%	0	87,100	$1,997,207	$0
Easton's and Atlantic Beach	98.36%	0	224,558	$5,149,114	$0
Peabody's and Third Beach	93.44%	8	20,695	$474,537	$49,347
Goddard Memorial State Park	97.54%	10	63,900	$1,458,200	$237,054
Bristol Town Beach	80.33%	1	8,583	$197,246	$7,135
Warwick Beaches	97.54%	11	85,277	$1,957,956	$349,412
Cedar Cove Club	23.77%	3	704	$16,195	$1,203
Coles River Club	31.97%	10	668	$15,370	$1,728

Table 3 (continued). 2018 Visitation, Closure, and Aggregate Value Data. Totals values represent 122 total days over the beach season (June, July, August, September).

Beach Name	% of Days with Data	Total Closure Days	Visits	Value of a Beach Day	Value Lost Due to Closures
Leeside	61.48%	7	6,391	$146,998	$2,382
Conimicut Point Beach	97.54%	14	32,322	$742,769	$177,889
Sandy Beach	59.84%	0	4,035	$92,723	$0
Warren Town Beach	95.90%	1	25,526	$587,091	$18,431
Barrington Town Beach	81.15%	0	4,488	$103,078	$0
Swansea Town Beach	96.72%	2	29,774	$684,809	$19,055
Pierce Beach	91.80%	9	7,774	$178,576	$19,176
TOTALS		76	601,796	$13,801,870	$882,813

Table 4. 2019 Visitation, Closure, and Aggregate Value Data. Totals values represent 122 total days over the beach season (June, July, August, September).

Beach Name	% of Days with Data	Total Closure Days	Visits	Value of a Beach Day	Value Lost Due to Closures
Scarborough State Beach	100.00%	3	58,400	$1,339,106	$47,835
Easton's and Atlantic Beach	100.00%	2	158,951	$3,644,738	$88,227
Peabody's and Third Beach	81.97%	8	10,751	$246,522	$32,097
Goddard Memorial State Park	100.00%	0	52,748	$1,203,704	$0
Bristol Town Beach	72.13%	1	5,332	$122,529	$669
Warwick Beaches	100.00%	0	85,617	$1,965,771	$0
Cedar Cove Club	39.34%	0	1,157	$26,604	$0
Coles River Club	72.95%	0	4,066	$93,510	$0
Leeside	70.49%	7	6,941	$159,651	$7,469
Conimicut Point Beach	100.00%	1	26,028	$598,128	$5,847
Sandy Beach	96.72%	0	10,865	$249,677	$0
Warren Town Beach	99.18%	0	15,876	$365,146	$0
Barrington Town Beach	38.52%	2	1,186	$27,250	$0
Swansea Town Beach	96.72%	0	15,346	$352,959	$0
Pierce Beach	100.00%	0	19,682	$452,096	$0
TOTALS		24	472,946	$10,847,391	$182,145

4. Policy Analysis – Non-Market Value Lost Due to Beach Closures

Once the ***Value of a Beach Day*** was calculated (Tables 3 and 4), we determined the impact that beach closures (due to high bacterial counts) had on the aggregate consumer surplus value for each beach. In order to determine the ***Value Lost Due to Closures***, we first had to compile the beach closure history for the selected beaches for 2018 and 2019 using EPA's BEACON 2.0 – Beach Advisory and Closing on-line Notification website. Once beach closure days were identified, it was necessary to determine the visits "lost" due to the closure. For this calculation, we used *"…67 percent fewer visits on a day with a closure…"* suggested by the Lyon et al. (2018) visitation model. This means that the visitation data on closure days only represents 33% of the expected visits for that particular day, based on model results. To calculate the ***Value Lost Due to Closures*** for each day with a closure, we used the following equation:

= ((***Visits*** / 0.33) x ***Consumer Surplus***) - ***Value of a Beach Day***

Using that value for each closure day, we were able to determine the total value lost each year due to closures (Tables 3 and 4). There were significantly more closure days in 2018 (76) compared to 2019 (24). That reduction in closures from 2018 to 2019 results in realized gain in value of:

2018 Value Lost		2019 Value Lost		Realized Gain in Value
$882,813	-	$182,145	=	$700,668

Bearing in mind the limitations and uncertainties noted above, there are several beaches that experienced a significant reduction in closures between 2018 and 2019; Goddard Memorial State Park, Warwick Beaches, Conimicut Point Beach, Coles River Club, and Pierce Beach (Tables 3 and 4). Together these beaches account for 53 less closures in 2019 compared to 2018, accounting for one more than the entire difference in closures between 2018 and 2019 (total closure difference was 52). An in-depth investigation of what drove the differences in closure between years is beyond the scope of this task. However, it is worth considering that improvements to wastewater and/or stormwater treatment are at least partly, if not wholly, responsible. Goddard Memorial State Park and Warwick Beaches were all identified as "High concern" beaches by NBEP. Goddard Memorial State Park is situated just outside of Greenwich Cove that receives the outflow from the East Greenwich Wastewater Treatment Facility. Although a cursory investigation did not reveal any significant upgrades or modifications to the facility, it is possible that protocols were implemented such that a local improvement in water quality resulted. City Park Beach, Oakland Beach, and Buttonwoods Beach are all located in the city of Warwick, RI which has been in the process of connecting residential properties to the sewer system to eliminate nutrient discharge associated with residential septic systems. As of 2017, the town was accepting bids to continue those efforts but our limited attempts to quantify those efforts with the Warwick Sewer Authority were unsuccessful. It is possible that some additional sewering between 2018 and 2019 was responsible for the observed reduction in closures at these beaches.

A potentially more likely explanation might involve the weather differences from one year to the next. For instance, 8 of the 10 closure days for 2018 for Goddard Memorial State Park occurred in the month of July while there were zero closure days in July 2019. A quick comparison of the National Oceanic & Atmospheric Administration (NOAA) daily precipitation records for Providence, RI between July 2018 and July 2019 shows that there was 2.67 times more rainfall in July 2019. More rainfall would be more consistent with wastewater and stormwater overflows, poorer water quality, and an increase in beach closures, but in this case, there were zero closures. Deacutis et al. (2006) suggest that severe drought can also negatively impact water quality by causing a decrease in estuarine circulation in the upper half of Narragansett Bay that usually manifests as widespread hypoxia and near-anoxic conditions. It is possible that the decreased precipitation in July 2018 relative to 2019 led to decreased circulation in Greenwich Cove and portions of Greenwich Bay, resulting in decreased flushing (or longer residence times) of waters containing harmful bacteria. Further investigation is needed to make any concrete connections, but we present this scenario to illustrate the notion that both natural and anthropogenic factors may need to be considered when planning a management action.

Despite the accuracy of the available closure data, closures are not always or immediately implemented when bacterial counts are high because of analysis delays. For instance, according to an article published in EcoRI News (Carini, 2019), Rhode Island Department of Health (RI DOH) officials acknowledged that decisions about beach closures "are made two days too late". The article referenced data from 2015 provided by RI DOH and Clean Ocean Access (COA) for Easton's Beach (Newport, RI) that showed there were only four (4) beach closures (totaling 10 days) despite 88 samples testing above the 60 colony-forming units (cfu) per 100 milliliters safe recreational use threshold. There are several existing models for predicting beach water quality developed by EPA and others that should help improve management of high-concern beaches. These improvements are likely to increase the number of beach closure days at all beaches, further increasing the ***Value Lost Due to Closures***, unless management actions are taken.

5. Policy Analysis – Non-Market Value Preserved through Hypothetical BMP

Understanding the ***Value Lost Due to Closures*** presents the opportunity to conduct a general cost-benefit analysis of the management actions versus the ecosystem service of concern. Based on the results outlined in the previous section, the 53 additional closures in 2018 over 2019 represent a loss in non-market value of >$700,000.00 (conservatively on the low side due to uncertainties in the visitation model). It is clear that any reduction in beach closures will diminish that lost non-market value, but how does that change in value compare to the costs associated with management actions?

To provide an example scenario, we examine the New England Interstate Water Pollution Control Commission (NEIWPCC), Narragansett Bay Estuary Program and the U.S. Environmental Protection Agency funded project titled "Sheffield Cove Innovative Stormwater and Pathogen Controls Jamestown, RI" (Gray, 2019). Sheffield Cove, located in Jamestown, RI, had a history of exceeding bacterial count benchmarks, particularly following rain events, that resulted in Rhode Island Department of Environmental Management (RIDEM) closing the cove to shellfishing. Although this example is not a beach, it provides an example of effective management actions and their implementation costs. 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. In addition, the plan included a Pet Waste Management Education plan since pet waste bacteria was identified as one component of the bacteria sampling. The BMP was projected to reduce the net loading of bacterial colonies per year by 26% and the total project cost was $118,200 (NBEP Grant Locations: A subset of NBEP funded projects from 1988-present).

The ***Value Lost Due to Closures*** presented in the previous section indicate that in 2018 Goddard Memorial State Park lost $237,054 due to 10 closure days, Warwick Beaches lost $349,412 due to 11 closure days, and Conimicut Point Beach lost $177,890 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% (a deliberately low assumption), the non-market savings would range from ~$18,000-$34,000 per year with a non-market value "payoff" within ~3.5-6.5 years. That payoff rate would be halved by a 20% decrease and, in the best-case scenario, immediate payoff with a 100% decrease in closures.
It is difficult to make a direct comparison between the Sheffield Cove Project and these particular beaches without knowing the exact bacterial counts compared to the closure threshold and exact

sources of the contaminants, but the exercise presented here provides a starting point for more detailed valuations and BMP comparisons in the future.

6. Origins and Demographics of Visitations

In addition to providing a way to model visitations to the selected SNEP beaches and estimate non-market values of the services provided by beach visits, the cell data also included the origins by census blocks and the demographics for those census blocks, which can tell us something about beneficiaries of these services. We used that information to summarize where the visitors were coming from (by state and county) and to characterize visitors by race, income, and age (for males and females separately) (Figures 3-9). The purpose of this section is to provide a summary of the origin and demographics information and highlight some noteworthy patterns that may be of interest to the SNEP region stakeholders.

The demographics information shown here is simply a representation of the demographics of each visitor's Census Block; demographic information for the exact individuals visiting from those Groups is not characterized in the source cell data.

For this section, we use the word "visitors" to indicate visitors from a Census Block from which the demographics information is derived.

For a comparison with overall SNEP region demographics, refer to the Task 2C section of this appendix.

Origin

Total visits (***Visits***) for each of the selected SNEP beaches were modelled using the cell data. Those visits are presented in Figure 3 for 2018 and 2019. Easton's and Atlantic Beach in Newport County, RI had the most visitors (150,000-225,000) of all the selected beaches. Those visitations were at least two (2) times higher than the visitations at any other beach. To provide insight into where those visitors were coming from, we examined the origin data (based on Census Block) in the context of origin state and origin county with an emphasis on area states and SNEP region counties (Figs. 4 and 5). As expected, the majority of the visitors to each beach are from the respective state except Barrington Town Beach whose visitors were largely from Massachusetts. Again, Easton's and Atlantic Beach standout from the other beaches in that Rhode Island visitors make up the largest individual group, but the majority of visitors are from other states. With respect to visitor origin counties, the majority of visitors are from SNEP counties, as might be expected. Easton's and Atlantic Beach are anomalous in that the single largest group of visitors are from "Other" counties (counties outside of the SNEP region) despite the majority of visitors being from SNEP counties. There is some relationship between visitor's county and beach county and the neighboring county for some beaches (e.g., 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 ~25% of Scarborough State Beach visitors are from Washington County).

Race

The cell data Race information for visitor census block groups were broken down into six (6) groups, "Asian", "Black", "Hawaiian Pacific", "Native American", "White", and "Other". The number of visitors to each of the selected SNEP beaches was grouped by race and presented as Percent Total Visits for 2018 and 2019 (Fig. 6). The majority (>85%) of people visiting these SNEP beaches are "White". That majority

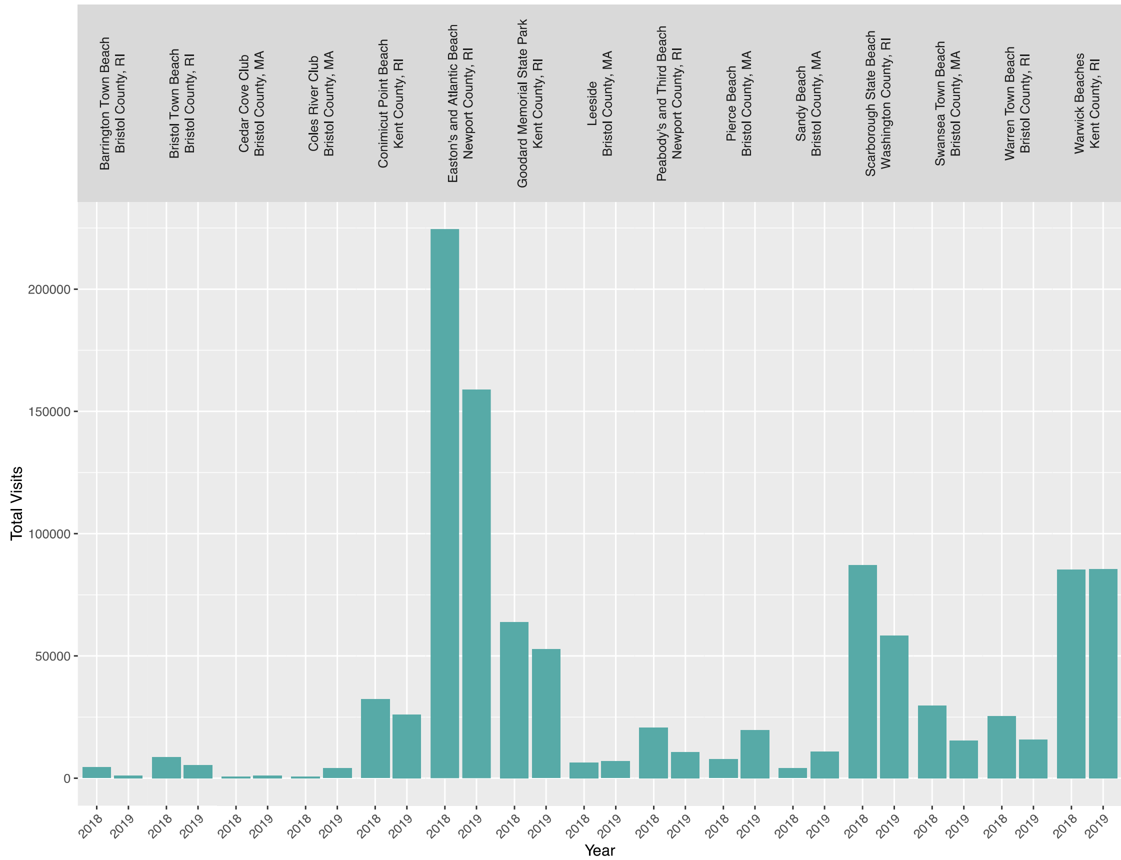


Figure 3. Total visits estimated from visitation model of Merrill et al. (2020) for select SNEP region beaches.

is even higher (>90-95%) in Massachusetts SNEP beaches. “Black”, “Asian”, and “Other” largely account for the 10-15% of the visitors not identifying as “White”, while “Native American” and “Hawaiian Pacific” visitors account for ≤5%.

Income

The income ranges for visitors to the selected SNEP beaches are plotted as Percent Total Visits in Figure 7. Greater than 60% of all visitors earn $100,000 or less, with a slight prevalence in most beaches to the lower income range except for Barrington Town Beach that has a clear predominance towards the upper income range.

Age

An examination of age data for both males and females (Figs. 8 and 9) reveals that for both sexes the 0-20 and 60+ age groups account for 50% of total visitations. For males, that percentage is split nearly evenly at ~25% for each group while for females the 60+ group generally accounts for slightly more than 25% while the 0-20 group generally accounts for slightly under 25%. Working-age groups for both males and females (20-29, 30-29, 40-49, and 50-59) account for the remaining 50% of all visitors with the 20-29 and 30-39 age groups making up similar, smaller proportions (each group ~10%) and the 40-49 and 50-59 age groups making up similar, larger proportions (each group ~15%).

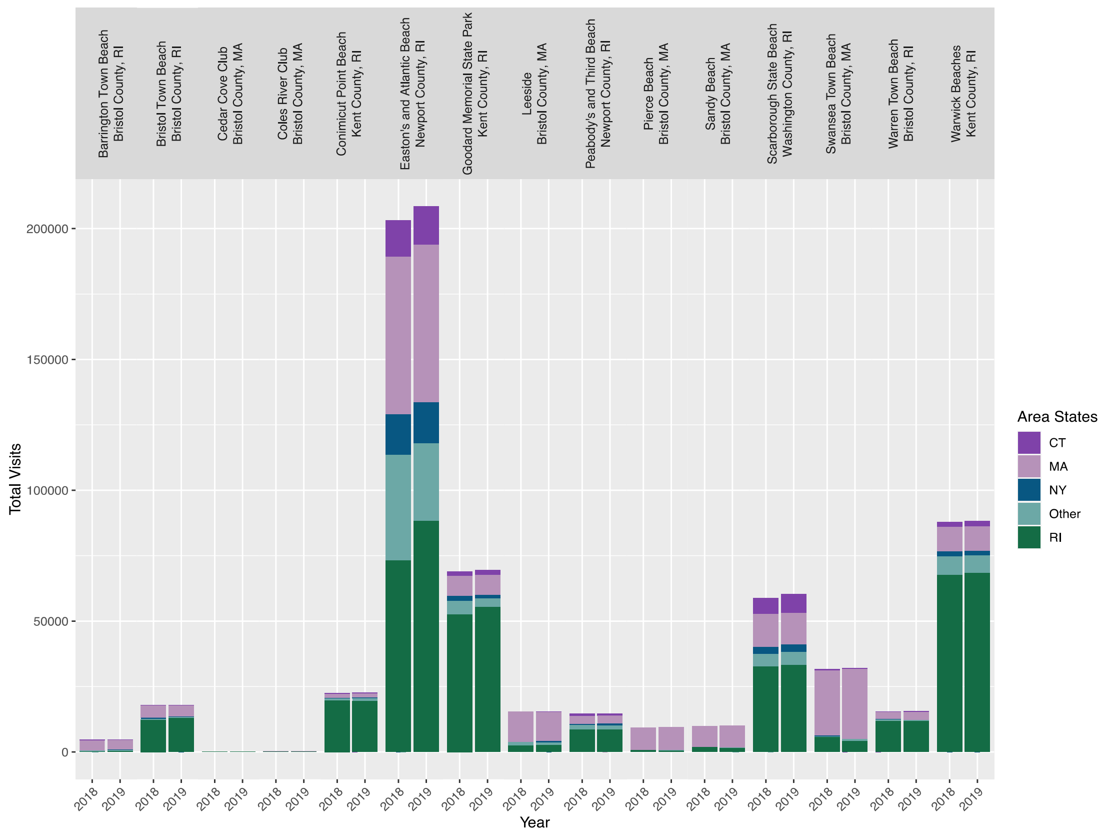


Figure 4. Total visits from SNEP area states (CT, MA, NY, RI) and Other states for 2018 and 2019.

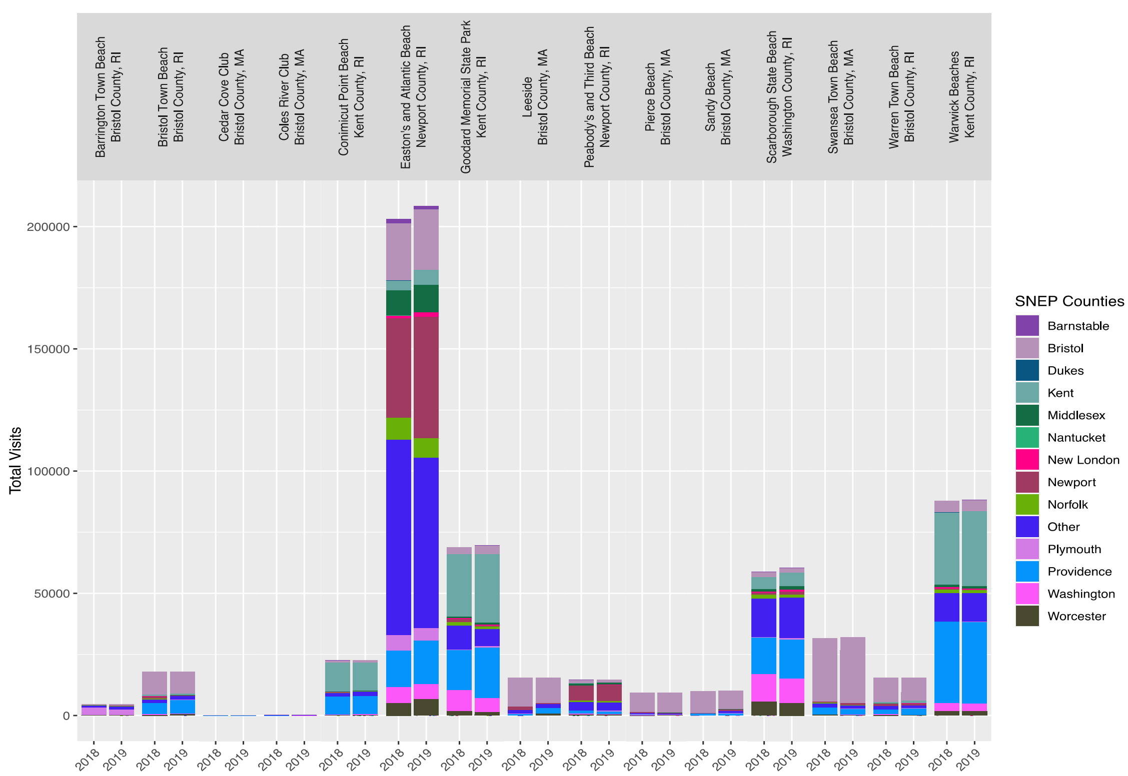


Figure 5. Total visits from SNEP counties and other counties for 2018 and 2019.

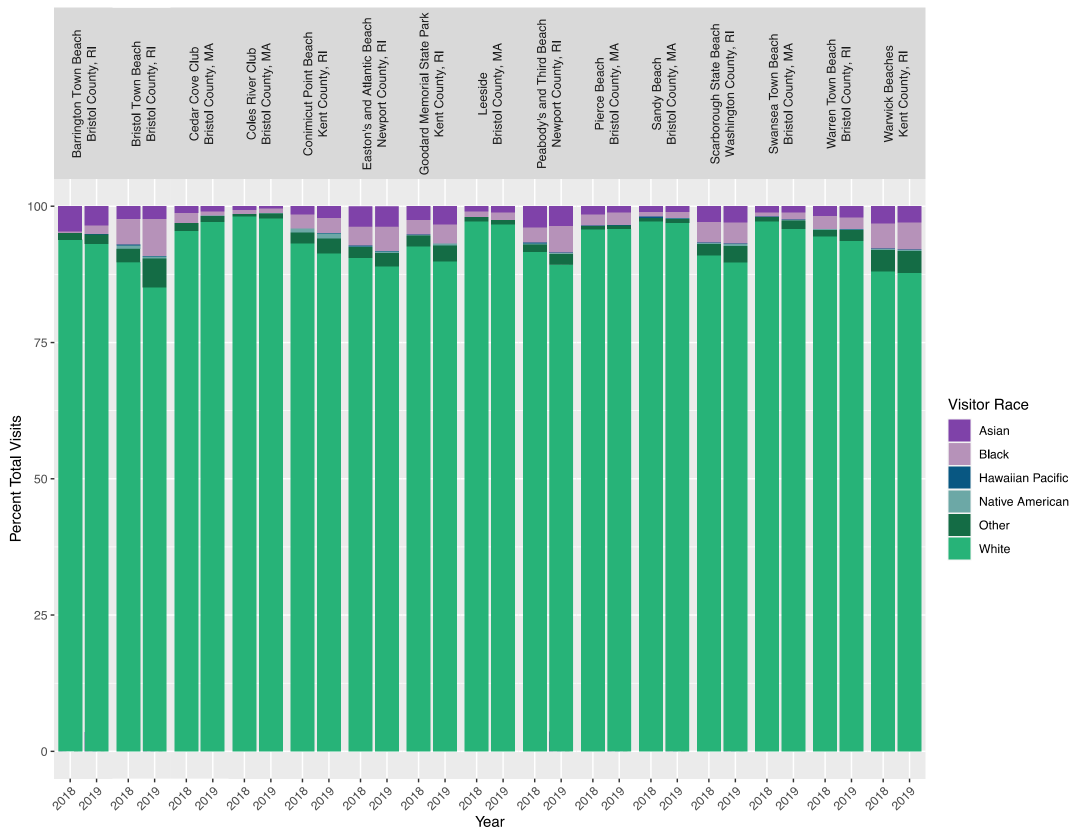


Figure 6. Percent total visits by race for 2018 and 2019.

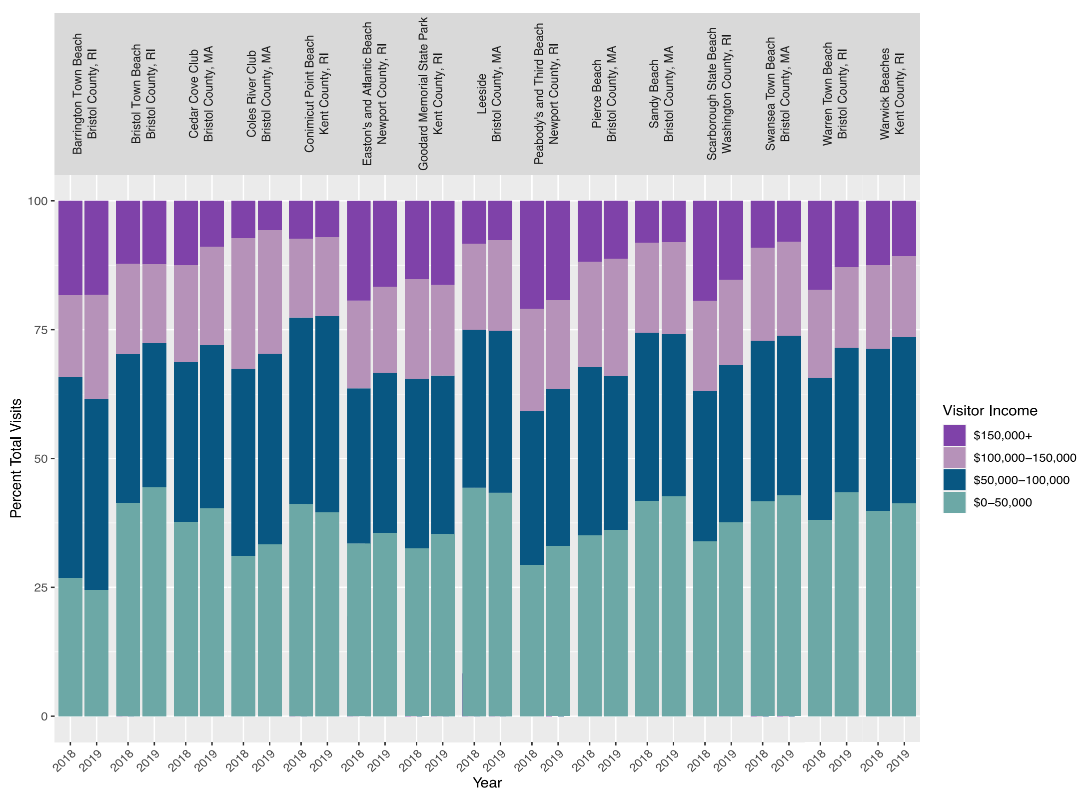


Figure 7. Percent total visits based on income for 2018 and 2019.

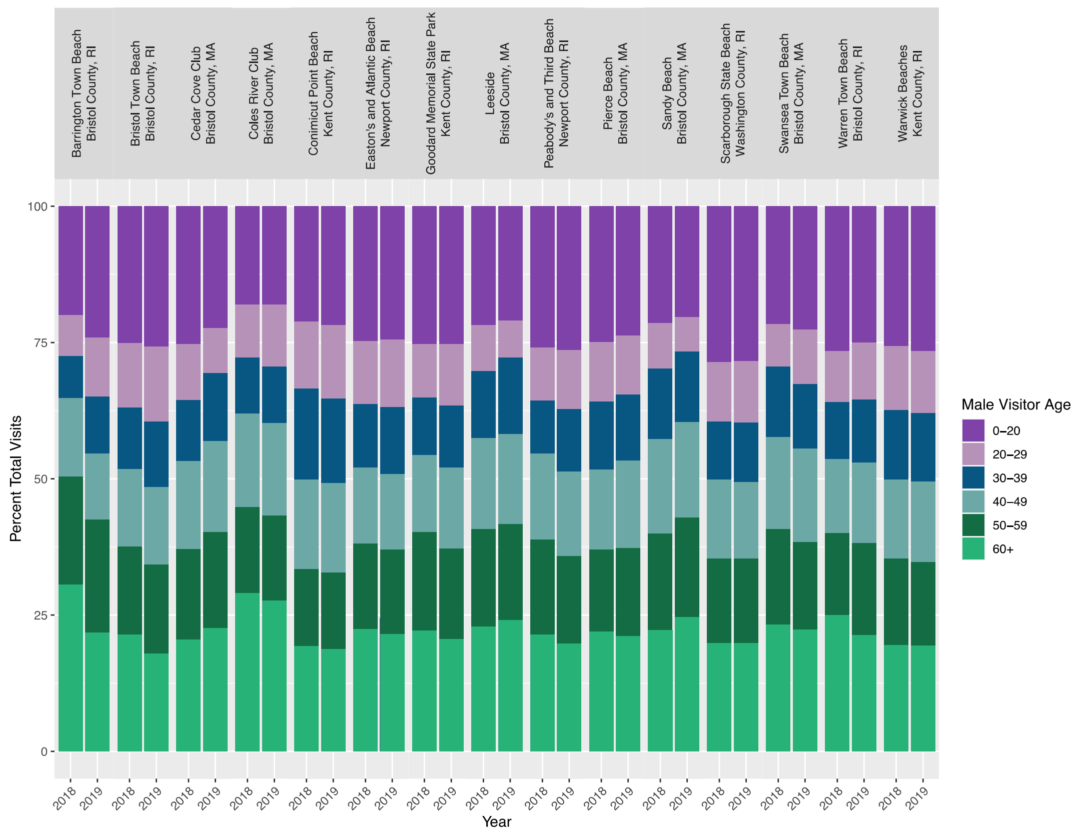


Figure 8. Percent total visits by male age for 2018 and 2019.

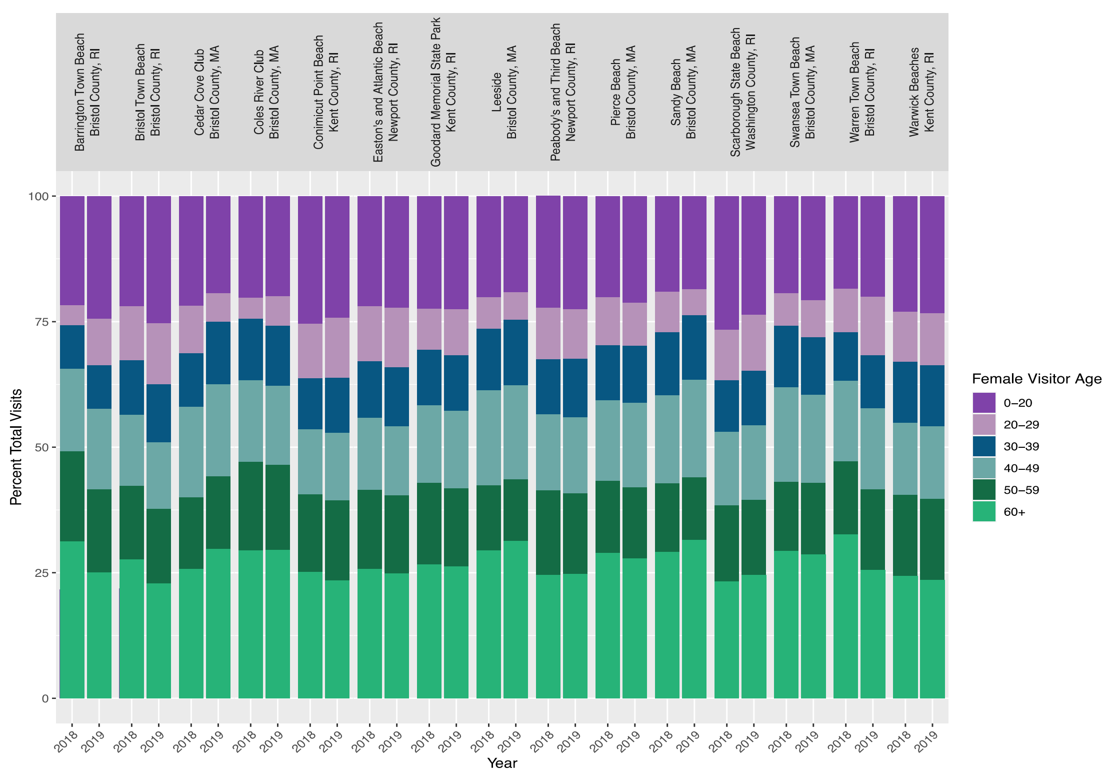


Figure 9. Percent total visits based on female age for 2018 and 2019.

7. An Assessment of the Pilot Valuation Exercise

One of the most complicated and uncertain components of the valuation described in this report is obtaining accurate visitation data. Visitations are commonly documented by municipalities and private beach clubs. Where visitation records are available, they are often based on car counts and an average number of people per car. These counts often do not take into account walk-on visitors or season pass holders. Fortunately, the EPA ORD advisors had previously created a visitation model using cell data and actual visitation data from beaches within the SNEP region (Merrill et al., 2020.) which provided a necessary estimate of visitations for the selected beaches used in our valuation.

Following the suggestion of the ORD task advisors, we attempted to obtain additional visitation data to validate and/or improve the visitation model. To do so, we emailed and/or called the appropriate state, municipal, and private points of contact requesting any visitation data they might have for 2018 and 2019, the years for which we had cell data (see Appendix 1 for contact information). We received three responses and only two of those provided visitation data (Third Beach, Middletown, RI and Scarborough Beach, Narragansett, RI). The data from Third Beach was annual summaries of parking passes sold for each year and the Scarborough data were total car counts by month for each year with an estimate of 3.2 people per car. The annual summaries from Third Beach did not allow for more than a yearly validation, but the Scarborough data provided the opportunity to compare the monthly totals from counts versus the visitation model.

The results of Scarborough Beach monthly comparison showed that the visitation model counts were 3-4 times lower (~34,000-63,000 counts lower) for June, July, and August 2018 and 4-5.5 times lower (~37,000-110,000 counts lower) for June, July, and August 2019 (Tables 5 and 6). In contrast, the counts for September 2018 and 2019 were 1.2 times higher (15,787 counts higher) and 4.4 times higher (14,230 counts higher), respectively. It is not clear why the pattern changes in September, but it is evident that the car count-based visitations are lowest in that month for both years. The visitation estimates based on car counts are made using 3.2 people per car, so that may be a potential source of error, but even if the counts used 1 person per car, the counts would be higher than those estimated using the visitation model. Also, the car counts may not consider walk-on visitations, however Scarborough beach is likely to have low numbers of walk-on visitors due to its location and relatively ample parking. It may be that the visitation model estimates are low because the model does not accurately account for cell phone owners/users. Regardless of the reasons, the visitation model would benefit from additional real visitation counts on the same daily frequency as the cell data.

Table 5. Comparison of Car Count Visits for Scarborough Beach to Visitation Model Visits for 2018.

	June	July	August	September	Annual Aggregate Value
Car Count total visits	49,830	124,256	95,286	13,117	$6,477,487
Modelled total visits	15,102	31,460	32,454	28,904	$1,997,207
Difference	34,728	92,796	62,832	15,787	$4,480,280

Table 6. Comparison of Car Count Visits for Scarborough Beach to Visitation Model Visits for 2019.

	June	July	August	September	Annual Aggregate Value
Car Count total visits	49,206	134,774	78,275	3,258	$6,088,227
Modelled total visits	12,044	25,386	16,079	17,488	$1,339,106
Difference	37,163	109,389	62,196	14,230	$4,749,121

If we consider the visitation discrepancy in the context of ***Annual Aggregate Value*** (Tables 5 and 6), there is a significant difference in non-market value. For instance, the ***Annual Aggregate Value*** for Scarborough State Beach for 2018 based on the visitation model visitation estimates is $1,997,207 compared to $6,477,487 for the car count-based visitation estimates. For 2019, the 2018 and 2019 ***Annual Aggregate Value*** values were $1,339,106 and $6,088,227, respectively. The difference equates to ~$4.5 million dollars for each year. Those huge differences in magnitude highlight the need for improved visitation estimates in order to better understand the significant non-market value that these beaches, and SNEP region beaches in general, provide to the SNEP region. Visitation estimates could be improved by collecting and maintaining detailed visitation counts from SNEP region beaches, particularly those considered high concern with respect to closures.

With respect to the practical execution of this task, we benefited immensely from the work that our ORD task advisors had already completed or were actively working on in their efforts to assess the non-market value of beaches within the region. This included the methodology outlined in Lyon et al. (2108), the purchase of cellular data, and the processing of cellular data to provide visitation estimates (Merrill et al., 2020), demographic information, and origin information synthesized in this report. Without the significant existing materials, methods, and models, this valuation exercise could not have been achieved in the time frame of this contract. Having said that, the valuation exercise described in this report has proven valuable in identifying areas needing improvement in the valuation process. In addition, the results of the valuation presented a first-order estimate of non-market valuations for SNEP region beaches, the potential lost value due to closures, and provided an initial framework for considering the costs and benefits of best management practices that could be employed to reduce those closures and their associated non-market value losses.

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Appendix 1 – Contact Information for Beach Visitation Data

Beach Name	Contact Organization	Contact Person	Contact Information	Contact email	Contact phone
Barrington Town Beach	Town of Barrington		Department of Parks and Recreation	recreation@barrington.ri.gov	
Bristol Town Beach	Town of Bristol		Department of Parks and Recreation	recreation@bristolri.gov	
Warren Town Beach	Town of Warren		Department of Parks and Recreation	warrenrecreation@gmail.com	
City Park Beach	City of Warwick		Department of Parks and Recreation	warwick-rec@warwickri.com	
Conimicut Point Beach	City of Warwick		Department of Parks and Recreation	warwick-rec@warwickri.com	
Goddard Memorial State Park	Rhode Island Department of Environmental Management	Jennifer Ogren	Assistant Administrator, Bureau of Natural Resources and Parks, Division of Parks and Recreation	Jennifer.Ogren@dem.ri.gov	(401) 667-6200
Oakland Beach	City of Warwick		Department of Parks and Recreation	warwick-rec@warwickri.com	
Atlantic Beach Club	City of Newport			lcapek@cityofnewport.com	
Easton's Point Beach	City of Newport			lcapek@cityofnewport.com	
Peabody's Beach	Town of Middletown	Will Cronin	Operations & Facility Manager	wcronin@middletownri.com	(401) 842-6519
Third Beach	Town of Middletown	Will Cronin	Operations & Facility Manager	wcronin@middletownri.com	(401) 842-6519
Scarborough State Beach - North	Rhode Island Department of Environmental Management	Jennifer Ogren	Assistant Administrator, Bureau of Natural Resources and Parks, Division of Parks and Recreation	Jennifer.Ogren@dem.ri.gov	(401) 667-6200
Scarborough State Beach - South	Rhode Island Department of Environmental Management	Jennifer Ogren	Assistant Administrator, Bureau of Natural Resources and Parks, Division of Parks and Recreation	Jennifer.Ogren@dem.ri.gov	(401) 667-6200
Pierce Beach	Town of Somerset		Department of Playground & Recreation		(508) 646-2808
Cedar Cove Club	Private Beach Club	Kyle Lloyd		kylelloyd1975@gmail.com	
Coles River Club	no info				
Leeside	no info				
Sandy Beach	Town of Swansea		Park Commission		(508) 675-1962
Swansea Town Beach	Town of Swansea		Park Commission		(508) 675-1962

SNEP Indicators and Metrics
Update and Synthesis Webinar Summary
September 25, 2020

On September 25, 2020, the contract team convened the SNEP Monitoring and Ecosystem Services Subcommittees to present final findings, results, and future applications of the project.

You can view the recording of Session 1 here.

If you would like to obtain copies of the individual the presentations, please email Alexandra.phillips@erg.com

Agenda

Presentation	Presenter
Session 1: Collecting and Organizing Monitoring Data	
Indicators and Metrics / IESF Overview	Emily Shumchenia, E&C Enviroscape
Monitoring Program Inventory	Hannah Stroud, ERG
SNEP-funded Project Monitoring Inventory	Craig Voros, GLEC
Development of an IESF	Chip Heil, E&C Enviroscape
Mapping IESF Components and Collecting Social Media Data	Emily Shumchenia, E&C Enviroscape
Session 2: Using the Integrated Ecosystem Services Framework	
Final Synthesis and Q&A	Emily Shumchenia, E&C Enviroscape

Session 1: Collecting and Organizing Monitoring Data

During the first session of the webinar, the contract team presented summaries of key findings from each task of the research plan. After each presentation, webinar participants had the opportunity to ask questions.

Indicators and Metrics / IESF Overview

Emily provided an overview of the project including the overall project scope and goals, highlights from past meetings, and key terminology.

Monitoring Program Inventory

Hannah presented on the monitoring program inventory. She outlined methods used to create and categorize the inventory, presented results from the inventory analysis, and shared conclusions and recommendations.

Q&A

Q: Can you clarify the difference between indicators and metrics?

A: For this work, we use the two terms together to represent data being measured. Generally, “metrics” refer to anything being measured (e.g., DO, acres of salt marsh) while “indicators” are metrics linked to a concept (e.g., DO is an indicator of water quality, salt marsh is an indicator of ecosystem health). As

SNEP proceeds with this work, the distinction will become more important, and we recommend explicitly defining the terms and using them more deliberately.

SNEP-funded Project Monitoring Inventory

Craig presented the results of the SNEP-funded inventory of water quality monitoring projects. He gave an overview of the information collected on each project and summarized the results of the inventory analysis.

Q&A

Q: Could these projects easily be entered into the same framework as the program inventory? Do the program's indicator categories apply to the projects as well?

A: It's plausible. Most projects have very specific focuses, the project's tasks and goals could inform how it would fit into the categories.

Q: Where is the SNEP-funded water quality data going? Does it get pushed up to the National Water Quality Portal?

A: A lot of projects do not put their data on the National Water Quality Portal. This is a good question to keep in mind for funding future projects–could make it a requirement.

Q: Did you find the monitoring that took place was sufficient to confirm the success of the project's objectives?

A: One-off monitoring/short term projects may show results once, but that might not be applicable in the long run. Projects with shorter timelines make it hard to draw conclusions about achieving long-term goals such as water quality improvement in a water body.

Q: For future projects, would it make sense for EPA to require projects to state if outcomes were achieved?

A. Yes. Not every project had a final report, so we had to make a lot of calls to get that information. Most projects did not identify if they achieved their aims. Sometimes they did achieve their aim, but they did not identify if that improved an ecosystem service, etc.

Q: Is there a way to aggregate results of the monitoring efforts to draw any general conclusions?

A: It depends on the question. We can draw make general statements about what projects are funded and what they measure, but the metrics used vary greatly. It's hard to condense the parameters monitored in a meaningful way.

Development of an IESF

Chip presented on the development of the IESF. He summarized the concepts behind the framework, shared how the team developed the IESF database, and outlined how the final IESF can be used to connect indicators and metrics with ecosystem services and beneficiaries. Finally, he shared recommended next steps for the IESF.

Q&A

Q: Should every indicator and its associated metrics also discuss their final ecosystem good and services and benefits?

A: Ideally, yes. That would help us communicate the need for conducting monitoring projects and justify the money that is required to both the community itself (tax dollars) but also to the federal level (larger programmatic funding agencies). This is a complicated framework that will help us conceptualize those linkages more clearly.

Q: How do you decide when to use the IESF?

A: You could use the IESF at the onset of a project when you are trying to justify funding. Funding is limited, and everyone wants a piece of the pie. The more links you can make among indicators and metrics and ecosystem services and beneficiaries the better. This can also help to establish the larger social impact. Scientists need to make the case about why their metric is the best one or why it deserves funding (i.e., look at what this water quality indicator can be used for, and look how many people can benefit from us monitoring this.)

Also, the links between these components are always there, whether we acknowledge them or not. Communicating them to the public could also occur periodically in "State of" reports so that communities understand why monitoring is happening and what results management actions are having.

Q: The grant period is typically relatively short compared to the amount of time needed to achieve measurable changes in environmental conditions and quantify that in terms of an ecosystem services metric. Did you identify some good examples of how to overcome this challenge?

A: Before we can answer that question, we must understand who is measuring the delivery of ecosystem services. Monitoring activities in the inventory focused on capturing changes in environmental conditions, and very few looked for the resulting impact on ecosystem service existence and use by communities. We did not provide specific examples of how to overcome that challenge.

One solution could be to require grantees to write about what progress they achieved towards their goals, even if they were not completely successful. Questions to consider include: What is sufficient to know if the management practice was successful? How long do we use that that data to determine if we made long lasting changes?

Q: Can you provide an example of how the database could be used to explore the connections between categories?

A: In the spreadsheet, you could follow a row across and see the connections among all the subgroups for beneficiaries and ecosystem services. The best way to see the connections is to go into the database with a specific question or indicator/metric in mind. From there you could generate the diagram to use for communication. The schematic is "automatically" generated from the database using code, so it does not have to be manually constructed. However, there is no public-facing tool for users to make their own schematics yet.

Q: Were these linkages primarily generated by the subcommittees, or are there some/others that were included based on peer-reviewed data? How do you see this framework expanding in the future?

A: The linkages generally came from group discussions. They are not all supported by peer-reviewed literature, but SNEP could decide if that is necessary. In the future, we could include specific indicators and metrics from the project inventory of the SNEP region. SNEP could prioritize what indicators/metrics should go in and expand as needed.

Q: Projects such as improving local and regional planning to either prioritize restoration projects or to reduce impacts of future development have long timelines for impact and larger potential benefits than a parcel-specific construction/retrofit/site restoration project. The latter may have more easily measurable outcomes and benefits. But working with communities to reduce the impact of future development over the coming decades will have larger impact long term. Maybe the solution for something like that is to produce an estimate of build-out impacts from existing land use rules vs. proposed improved practices. This is just one example of the kinds of things we grapple with regularly.

A: This is an important message and something that the IESF hopefully will inform if we start putting a scale and numbers to some of the ecosystem services. One example is cutting down forests for solar panel installation. Solar energy is good, but what is the cost of cutting down all the trees? Longer-term impacts are hard to communicate.

The resulting discussion from Chip's presentation took up the remaining time allotted for session 1. Instead of giving her presentation on mapping IESF components and collecting social media data, Emily shared links to the interactive map and to a summary page of the twitter data collection and results. She also referred those interested in learning more about these tasks to read the final report and appendix.

Session 2: Using the Integrated Ecosystem Services Framework

Emily presented on the steps for using the IESF. She demonstrated how the IESF can be operationalized by going through each step using a sample management question. After the presentation, Emily led the group in a Q&A session and subsequent discussion.

Q&A

Q: Does this work reveal a need for a better set of commonly accepted and used terms representing indicator, metric, measures, system attributes, etc. to better afford comparability across programs?

A: Yes, we have reached a point where we need to establish common terms and standard language. EPA is working on creating a standardized list of ecosystem services.

Q: Is there a way to build in strength and certainty of relationship in connecting lines in IESF? As a "ranking" tool or as way to represent a "ranking" result from a related protocol, is there a way to understand what drives the relationship?

A: Using line width is a great idea. This could easily create a new factor to visually represent strong or weak lines. It could also create subcategories identifying stressor or response variables (see NBEP State of the Bay).

Q: Many states have not realized the value of figuring out how many people come to their beaches, especially out of state visitors. Is it possible to identify some minimum types of data that EPA could recommend that resource managers should collect?

A: Yes, SNEP could develop general best practices based off programs we inventoried and surveyed. The final report includes town-specific data collected.

Q: The value of a beach closing will almost always lag actual exposure to a waterborne pathogen (monitoring timing) and not reveal associated health costs. Did you think about how to incorporate a beach closure day with the pathogen exposure that occurred before or after the closure?

A: We did not address the cost of getting sick. The losses are on the low end because some of the closures are not perfectly synced up with the exposure event. Losses would be worse if we closed beaches at the exact time of high bacterial counts.

Q: For many indicators, we look at progress toward measurable goals (e.g., meeting water quality standards.) How do we quantify how that translates to ecosystem service values for communities across the estuaries' watersheds? For example, what is the cost of algal blooms in lakes and ponds? How do we quantify progress when there are many factors involved (e.g., nutrient inputs, precipitation, and temperature variations over time)? How do you factor in ongoing work to reduce impacts while simultaneously acknowledging increased impacts from new development? What is the ecosystem service value gained or lost for the associated human and wildlife communities?

A: We hope the IESF will be used to make this information available to the public and lead to broader community support.

Discussion Points

- There is a lot of error with both valuation per day and visitation, but understanding visitation is still critical. There is an ORD report on how to collect onsite beach visitation counts, and there will always be high variability and error–similar to wildlife population estimates.
- The IESF is one of a few/several current efforts to reveal relationship between complex systems in the human-environmental coupled systems. It would be a good idea to select a smaller set of visual tools.
- If the IESF can help trace back the primary influencers/drivers of change, we could more easily identify critical points of leverage for decision making and policy development. We could have a more effective view of how the system changes and might be more efficient in building an evidence-based response.
- We want to end up with a hierarchy of monitoring and have long-term goals, state of the region reports, etc. But we lack good resilience indicators (i.e., the insurance value of having the ecosystem relatively intact and functioning.)
- SNEP should prioritize water quality data. However, existing water quality data is messy and will be a big lift to synthesize it well enough to draw linkages.
- SNEP should also focus on equity issues such as creating more green spaces, etc.