AR-390

FINAL REPORT

How People Benefit from New Hampshire's Great Bay Estuary

A collaborative assessment of the value of ecosystem services and how our decisions might affect those values in the future

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NOAA Office for Coastal Management (OCM)
Silver Spring, MD

New Hampshire Department of Environmental Services Coastal Program (NHCP)
Portsmouth, NH

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(Under contract to the NOAA Office for Coastal Management)

This report documents the work conducted under the Great Bay Ecosystem Service Assessment (GBESA) project. The GBESA was a collaborative effort between

- The New Hampshire Department of Environmental Services Coastal Program (NHCP),
- The Piscataqua Region Estuaries Partnership (PREP),
- The Nature Conservancy (TNC),
- The Great Bay National Estuarine Research Reserve (GNBERR),
- NOAA's Office for Coastal Management (OCM), and
- Eastern Research Group, Inc. (ERG; as a subcontractor to NOAA OCM).

The report was written as a collaborative effort between ERG and the NHCP, with input on drafts being obtained from the other partners above and other stakeholders in the process. Nevertheless, NOAA and ERG are responsible for the final content of the report and any errors or omissions herein.

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Executive Summary

New Hampshire's Great Bay Estuary is recognized for its national importance as part of EPA's National Estuary Program and NOAA's Estuarine Research Reserve System. Like many other estuaries around the country, the Great Bay Estuary faces ongoing pressures including but not limited to population growth and development, marine transportation, boat moorings, pathogens, invasive species, eutrophication, and climate change. In 2010, a diverse group of partners, led by the Piscataqua Region Estuaries Partnership (PREP), laid out management goals to address these issues in the Piscataqua Region Comprehensive Conservation and Management Plan (CCMP) (PREP, 2010). Substantial investments were made in oyster, saltmarsh, eelgrass, and fisheries restoration efforts. There are also major water quality improvement efforts underway with regards to stormwater control and waste water treatment facility effluent permits, as well as greatly intensified interest in oyster aquaculture. Coastal resource managers and stakeholders are interested in utilizing emerging planning tools and processes to more holistically plan and implement estuarine conservation and restoration efforts and address issues associated taking place on and around the water.

In 2013, the New Hampshire Department of Environmental Services Coastal Program (NHCP), PREP, and The Nature Conservancy (TNC) secured a National Oceanic and Atmospheric Administration (NOAA) Coastal Management Fellow to lead the Great Bay Ecosystem Services Assessment (GBESA). The goal of the GBESA was to better understand the ways people benefit from Great Bay Estuary ecosystems and inform decisions to sustainably maximize those benefits while reducing conflict. The Project Team identified five objectives within this overarching goal, including:

- Test an ecosystem services and economic valuation approach in the region,
- Conduct a spatial integrated assessment using available spatial data,
- Develop outreach and communications materials targeted at specific audiences,
- Identify key opportunities to improve management and maximize ecosystem services, and
- Engage partner organizations.

The Project Team, with a Stakeholder Advisory Committee (SAC), also agreed to focus on three habitats in the Bay: salt marshes, oyster beds, and eelgrass.

During Phase 1 of the project, the Project Team and the SAC developed two future management scenarios reflecting potential extremes for the Great Bay Estuary in 2025:

- The Gain and Sustain Habitats and Benefit scenario ("Gain and Sustain scenario" for short). This scenario reflected improvements in management and conditions in the Bay.
- The Lose Habitats and Benefits scenario ("Lose Habitats" scenario for short). This scenario reflected a decline in conditions in the Bay as well less active management of conditions in the Bay.

The Project Team and SAC also defined a set of conditions to reflect the current conditions of the Bay (referred to as the Current Conditions scenario).[1] The Project Team combined available spatial data to perform a habitat risk assessment for the three habitats. The risk assessment resulted in an estimate of the number of acres for each habitat under each scenario. These estimates are summarized in Figure ES-1.

[1] The Current Conditions scenario reflects the 2012-2013 time frame.

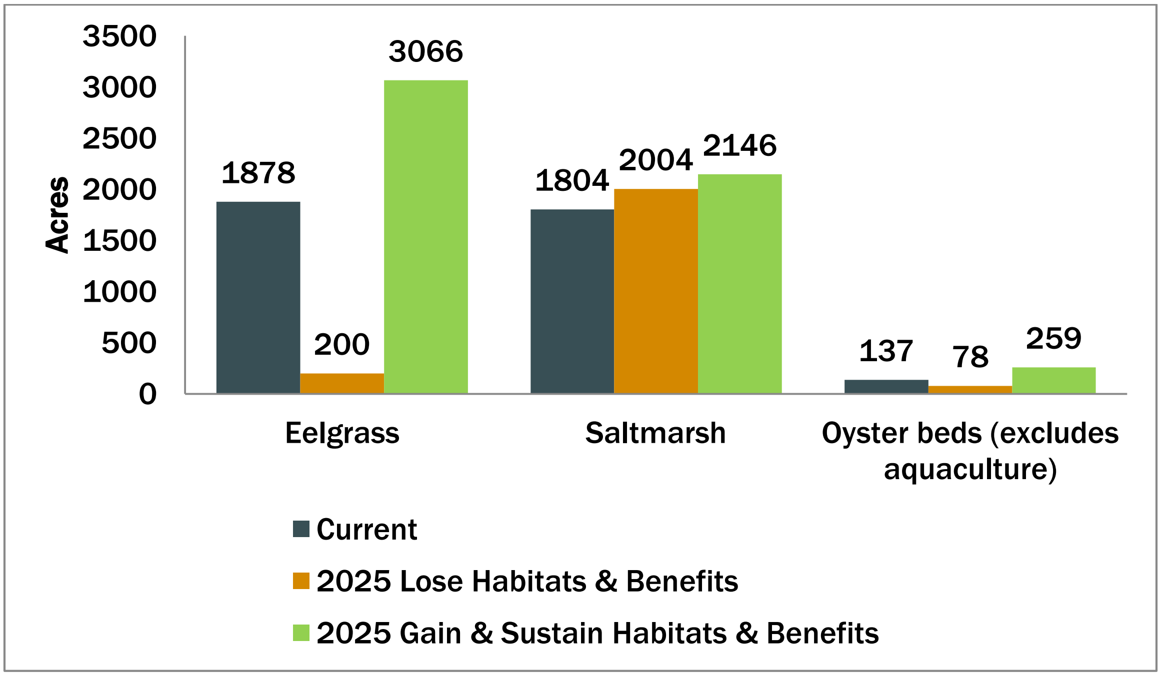


Figure ES-1 - Habitat Risk Assessment Results: Acreage of Habitats for Current Conditions and Two Future Scenarios

For Phase 2 of the project, NOAA provided funding to hire Eastern Research Group, Inc. (ERG) to assist with the ecosystem services assessment and economic valuation and to continue to engage stakeholders, including an emphasis on engaging the Great Bay National Estuarine Research Reserve (GBNERR). During Phase 2, the Project Team also conducted a series of three SAC meetings to gain input from stakeholders on the economic valuation work being performed and on a set of graphics used to convey the results of the analysis. The economic valuation work performed under the project focused on seven ecosystem services:

- Existence value: the value that people place on the existence of a resource. This was estimated for each of the habitats.
- Recreational fishing: the value that recreational anglers place on being able to take additional trips to Great Bay.
- Recreational oyster harvesting: the value recreational oyster harvesters place on additional harvesting in Great Bay, measured in terms of increased numbers of licenses sold.
- Commercial oyster aquaculture: the increased value to commercial aquaculture farms from expanded acres open to commercial aquaculture.
- Commercial fishing: the value in terms of increased annual commercial catch associated with the increased biomass productivity from the difference in acres for salt marshes and eelgrass between the Gain and Sustain and the Lose Habitats scenarios.
- Carbon sequestration: the value in terms of reduced global harm (e.g., changes in net agricultural productivity, human health, property damages from increased flood risk, etc.) associated with increased sequestration of carbon in the Gain and Sustain scenario compared to the Lose Habitats scenario.
- Nitrogen removal: the value in terms of reduced pollutant treatment costs to local municipalities for reducing nitrogen in the water column.

The final estimate for each ecosystem service is presented in Table ES-1.

Table ES-1
Summary of Economic Valuation Estimates Reflecting Projected Difference in Acres in 2025 Comparing the Gain and Sustain Scenario to the Lose Habitats

Ecosystem Service	Habitat	Estimated Economic Value in 2025 (phrased in 2015 dollars)
Existence value	Salt marshes	$1.6 million
	Eelgrass	$40.2 million
	Oyster beds	$0.7 million
Recreational fishing	All	Variable; depends on turbidity and improvements in dissolved oxygen
Recreational oyster harvesting	Oyster beds	$23,700
Commercial aquaculture	Oyster beds	$131,200 - $142,100
Commercial fishing	Salt marshes	$4,473
	Eelgrass	$1.7 million
Carbon sequestration	Salt marshes	$3,400 - $16,300
	Eelgrass	$49,100 - $81,600
	Oyster beds	$2,700
Nitrogen removal	Salt marshes	$608,300 - $688,800
	Eelgrass	$13.1 million - $14.8 million
	Oyster beds	$5.3 million - $6.0 million

1 Background

New Hampshire's Great Bay Estuary is recognized for its national importance as part of EPA's National Estuary Program and NOAA's Estuarine Research Reserve System. Like many other estuaries around the country, the Great Bay Estuary faces ongoing pressures including but not limited to population growth and development, marine transportation, boat moorings, pathogens, invasive species, eutrophication, and climate change. Figure 1 provides data and information highlighting the stressors impacting the Great Bay Estuary and the current health of the estuary. The decision-making mechanisms pertaining to all of these issues tend to be sector-specific and inadequately integrated even though they all affect the limited geography of the Great Bay Estuary. In 2010, a diverse group of partners, led by the Piscataqua Region Estuaries Partnership (PREP), laid out management goals to address these issues in the Piscataqua Region Comprehensive Conservation and Management Plan (CCMP) (PREP, 2010). Substantial investments were made in oyster, saltmarsh, eelgrass, and fisheries restoration efforts. There are also major water quality improvement efforts underway with regards to stormwater control and waste water treatment facility effluent permits, as well as greatly intensified interest in oyster aquaculture. Coastal resource managers and stakeholders are interested in utilizing emerging planning tools and processes to more holistically plan and implement estuarine conservation and restoration efforts and address issues associated taking place on and around the water.

1,023 number of square miles that form Great Bay estuary	population increase since 1990 19% / 120% impervious cover increase since 1990
nitrogen load from non-point sources 68%	38% eelgrass loss in Great Bay since 1990
6.6ft possible sea-level rise by 2100	loss of oyster population since 1993 91%
18 acres of oyster restoration completed since 2009	2 number of oyster farms in 2007 / 16 number of oyster farms in 2014

Figure 1
Factors Impacting the Health of the Great Bay Estuary
(Source: Adapted from PREP CCMP)

Management and conservation organizations active in the coastal region of New Hampshire have a strong track record of working collaboratively to address pressing management issues. There is a high level of interest in ensuring that estuarine restoration efforts provide maximum environmental and societal benefits through strategic use of limited staff and financial resources. There are excellent existing spatial datasets for the region's estuaries that include information on water quality, bathymetry, marine habitats (e.g., eelgrass, oysters, saltmarsh), fish and wildlife, human uses, and potential impacts of climate change. These datasets have been generated by researchers at the New Hampshire Department of Environmental Services Coastal Program (NHCP), the University of New Hampshire's Center for Coastal and Ocean Mapping, UNH Jackson Estuarine Laboratory, PREP, the Great Bay Estuarine Research Reserve (GBNERR), and The Nature Conservancy (TNC), among many others. There was a need, however, to combine these datasets into a spatially-explicit ecosystem services analysis that explores the benefits and potential costs associated with different future scenarios. By doing so, New Hampshire's coastal managers can be better prepared to evaluate and assess the value of the environmental and societal costs and benefits of action.

1.1 The Great Bay Ecosystem Services Assessment

In 2013, NHCP, PREP, and TNC (referred to as the Phase 1 Project Team) secured a National Oceanic and Atmospheric Administration (NOAA) Coastal Management Fellow to lead the Great Bay Ecosystem Services Assessment (GBESA). Together with a Stakeholder Advisory Committee (SAC), this group completed Phase 1 of the project which involved combining available spatial data to assess habitat risk and create future management scenarios. For Phase 2 of the project, NOAA provided funding to hire Eastern Research Group, Inc. (ERG) to assist with the ecosystem services assessment and economic valuation and to continue to engage stakeholders, including an emphasis on engaging the GBNERR. In Phase 2, the Project Team expanded to include NOAA, ERG, and GBNERR. Many regional partner organizations participated in the GBESA as stakeholder and expert advisors (see full list of the Stakeholder Advisory Committee (SAC) and Project Team members in Appendix A).

The goal of the GBESA was to better understand the ways people benefit from Great Bay Estuary ecosystems and inform decisions to sustainably maximize those benefits while reducing conflict. The project team identified five objectives within this overarching goal, including:

- Test an ecosystem services and economic valuation approach in the region,
- Conduct a spatial integrated assessment using available spatial data,
- Develop outreach and communications materials targeted at specific audiences,
- Identify key opportunities to improve management and maximize ecosystem services, and
- Engage partner organizations.

Figure 2 provides a map of the Great Bay Estuary highlighting the project area.

As a result of several discussions, the Project Team decided that the GBESA would be designed to address broad questions about future management rather than evaluate tradeoffs between specific options. This decision was made partly due to the multiple interests of the partners involved in the project and partly due to the limitations of resources and data. The Project Team identified several target stakeholders for the results, including organizations involved in habitat restoration (TNC, UNH), shoreline protection and dock permitting (New Hampshire Department of Environmental Services Wetlands Bureau), shellfish aquaculture permitting, commercial fisheries management, and recreational shellfish harvesting (New Hampshire Department of Fish and Game), and mooring siting and permitting (Pease Development Authority Division of Ports and Harbors). The stakeholders targeted for the results have shifted and expanded throughout the project, and more detail about the specific audiences that may find the GBESA results useful is given in Section 7.

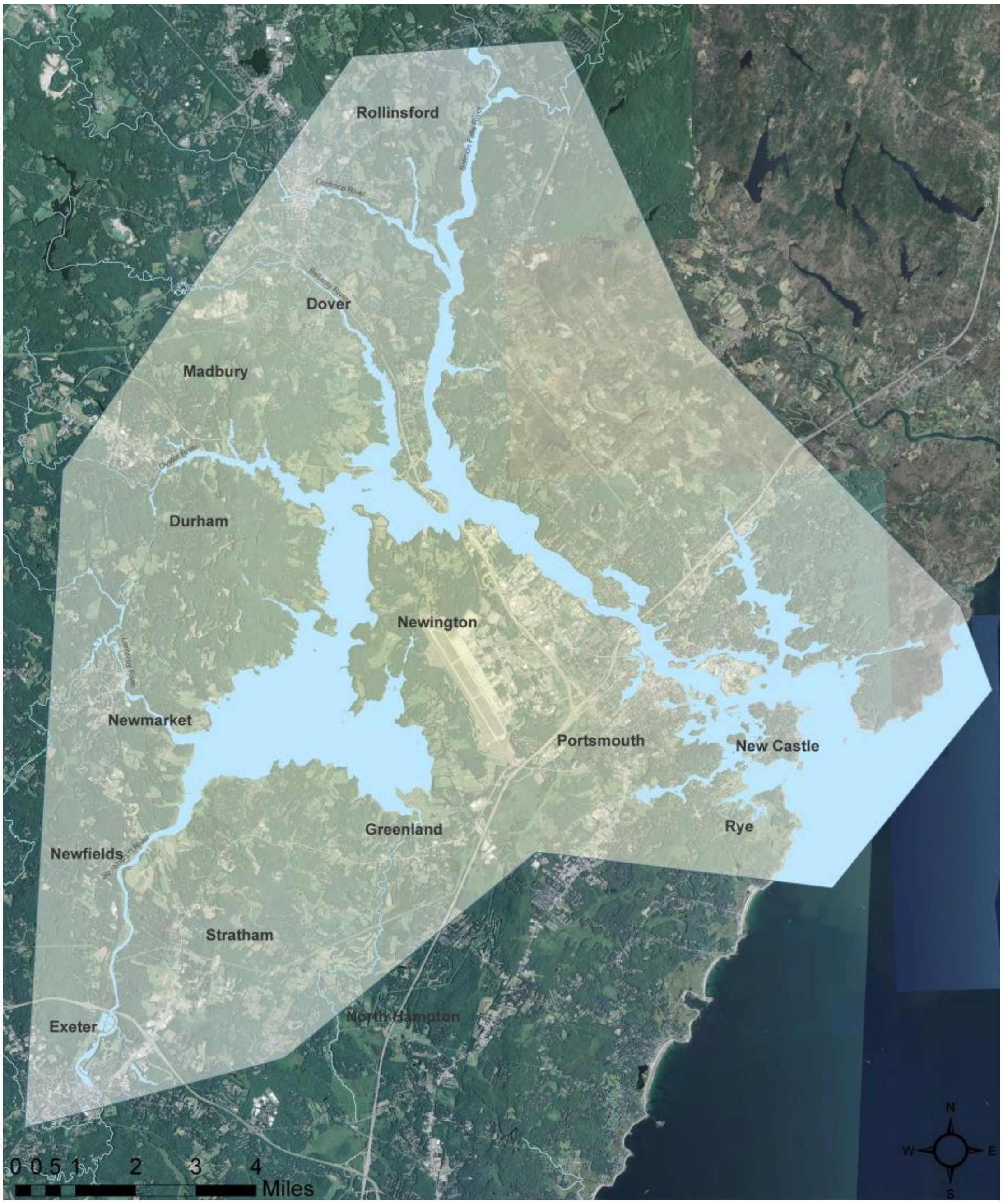


Figure 2
Map of Great Bay Estuary Identifying Project Area

1.2 Habitats, Ecosystem Services, and GBESA Conceptual Model

Ecosystem goods and services have been defined as the conditions and processes through which natural ecosystems, and their associated species, sustain and fulfill human life (Dore and Webb, 2003). Examples of ecosystem services are clean water and clean air, livable climates (carbon sequestration), and fulfillment of cultural, spiritual, and intellectual needs. Therefore, ecosystem services are also described as the benefits, both tangible and intangible, created by particular sets of ecological characteristics that are explicitly tied to social value (Olson et al., 2004; Ranganathan et al., 2008; Turner et al., 2003). In other words, ecosystem services are the outcomes of ecosystem functions that yield value to people; the benefits people get from nature. The ecosystem service values relative to marine and coastal resources are diverse. They are founded in the public's desire to conserve, recreate in, consume, profit from, and preserve marine and coastal environments. These values originate in society's ongoing interactions with the coast and coastal issues and are then expressed through the democratic process to those who make law and develop legislative policy.

As a first step in this project, a conceptual model was developed as part of the kick off workshop with the SAC. The group selected three of the key habitats that provide ecosystem services in the Great Bay Estuary and identified the stressors negatively impacting the habitats, the actions that can positively impact the habitats and the specific ecosystem services provided by the habitats. This model informed the Habitat Risk Assessment scenario development process as well as the ultimate selection of ecosystem services to evaluate and value. Figure 3 provides a graphic depiction of the GBESA conceptual model.

The Great Bay Estuary conceptual model shows the three key service-providing habitats depicted in green in the center column (saltmarsh, eelgrass, oyster beds) along with an explicit recognition that each habitat type provides nursery habitat for fish species. The right column lists some of the important ecosystem services (dark blue) that the habitats provide to people. The left column includes a list of stressors (orange) that negatively impact the key habitats resulting in negative impacts to the ecosystem services provided by those habitats. The left column also shows management actions (light blue) that positively impact the habitats and, as a result, the ecosystem services they provide.

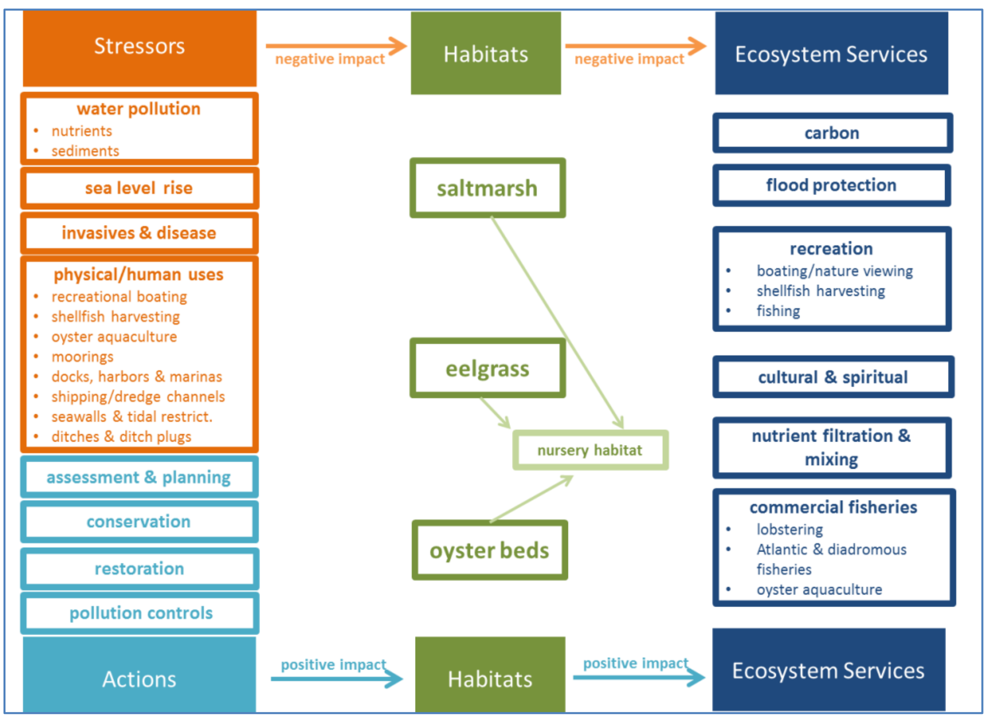


Figure 3
Conceptual Model of Great Bay Habitats, Stressors, Drivers, and Ecosystem services

1.3 Report Overview

This report summarizes work performed by the Project Team in two phases to develop the GBESA and is organized as follows:

- Section 2 provides an overview of the project beginning with a project timeline and discussing the major activities over the course of the project. A key feature of this work was the iterative process used by the Project Team in engaging with stakeholders. Specifically, the Project Team would perform project work, hold a SAC meeting to get feedback on the work, and then incorporate the feedback as the Project Team moved onto the next stage of the project.
- Section 3 details Phase 1, including the habitat risk assessment and scenario development work performed by the Phase 1 Project Team. The results from the work described in Section 3 form the backbone of this project and provide the key input into the valuation work performed under Phase 2.
- Section 4 describes Phase 2, including the work to place economic values on the differences between the future scenarios developed in Section 3.
- Section 5 describes the outreach and communication materials developed to convey the results of the GBESA.
- Section 6 discusses the transferability of the results from this project to other NERRS or other areas where valuing future scenarios would be useful to inform public discussions.
- Section 7 lays out lessons learned and priorities for next steps for the Great Bay Estuary as they relate to the development and use of ecosystem service information.

2 Project Overview

The GBESA consisted of two phases; a scenario development phase and an ecosystem service assessment phase. An overview of the project timeline and phases is given in Figure 4. Both phases are described in the sections that follow.

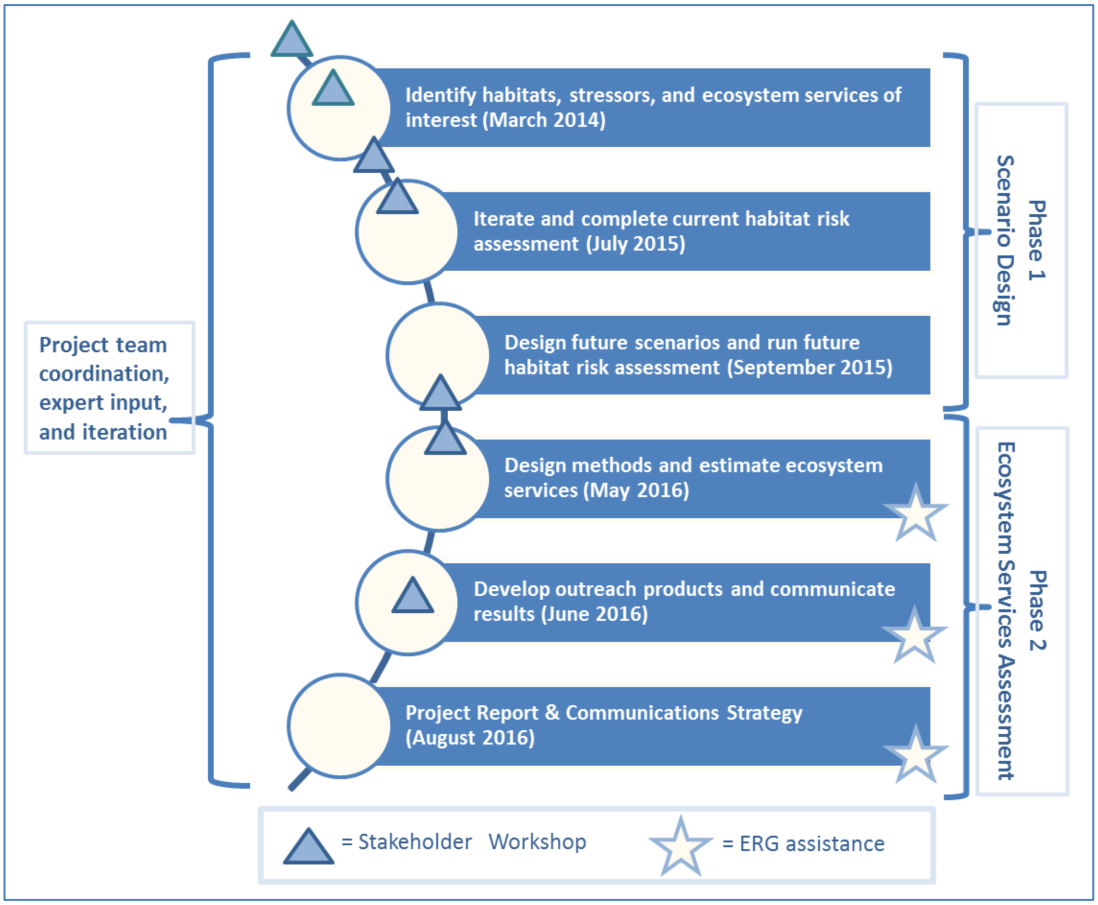


Figure 4
Project Steps and Timeline

2.1 Phase 1: Scenario Development

Once the conceptual model was finalized (see Figure 3), the SAC assisted the Project Team to compile a Current Conditions baseline map that roughly represented habitat areas for the years 2013 and 2014 in the Great Bay Estuary. The Project Team used existing spatial data about habitats and stressors, provided by SAC members and other sources, and the InVEST Habitat Risk Assessment (HRA) model (Arkema, et al., 2014) to ascertain relative risk to different habitat areas as a result of available spatial information about stressors on those habitats. Using the results of the Current Conditions HRA, the Project Team worked with the SAC to design two future management scenarios for the year 2025. These scenarios were intended to represent two extreme possible futures and are described in more detail in Section 3 and Appendix B. The degraded habitat future, intended to depict a continuation of historic trends and a lack of planning, was named 'Lose Habitats and Benefits' and the enhanced habitat future, based on the assumption that the 2010 CCMP management goals would be attained by 2025, was named 'Gain and Sustain Habitats and Benefits.'

2.2 Phase 2: Ecosystem Assessment

Under Phase 2, the GBESA Project Team (1) performed an economic valuation of the work developed under Phase 1, (2) facilitated a series of three additional SAC meetings to obtain feedback on the work being done by the Project Team under Phase 2, and (3) developed outreach materials to communicate the results of the valuation work being done. The first of the Phase 2 SAC meetings was held on November 19, 2015 to identify a set of ecosystem services to focus on based on the conceptual model developed in Phase 1. The first Phase 2 SAC meeting also allowed NHCP to present the initial results from the habitat risk modeling from Phase 1. A key outcome from the November 2015 SAC meeting was a set of ecosystem services for the Project Team to use in estimating economic values. ERG then spent time developing those value estimates; this is described in detail in Section 4. The Project Team then held a second Phase 2 SAC meeting on April 12, 2016 in which the Project Team presented the initial set of economic value estimates and discussed how those estimates could be communicated. The Project Team used the feedback from the April 2016 meeting to develop a revised set of estimates and an initial set of outreach materials. In the third Phase 2 SAC meeting (June 10, 2016), the Project Team summarized the revised estimates, presented the initial set of outreach materials, and facilitated discussion on the outreach materials and how they could be used. Finally, based on feedback from the June 2016 meeting, the Project Team developed this report. The valuation results are presented in the main text of this report while the descriptions and outcomes from the three Phase 2 SAC meetings are presented in Appendix C.

3 Phase 1: Habitat Risk Assessment and Ecosystem Scenario Development

This section provides a summary of the habitat risk assessment modeling performed by NHCP under this project. The full details of the modeling effort are provided in Appendix B. This section summarizes the Project Team estimates for the number of acres of each habitat in the current conditions and under the two future scenarios developed for the modeling effort. This section concludes with a spatial representation of the modeling results.

3.1 Current Conditions

Current conditions habitat, activity, and use mapping were used to represent the situation in the Great Bay Estuary circa 2012/2013. Through a multi-stakeholder process, three key habitats were identified that provide significant ecosystem services to people in the area. The key habitats are eelgrass, salt marsh, and oyster beds, including natural beds and restored beds. Information was also presented for acres leased for oyster aquaculture, because farmed oysters also produce important ecosystem services within the Great Bay Estuary.

Using data and information from scientific literature, expert and stakeholder knowledge and informed opinions, and existing spatial datasets, a spatial overlap analysis was conducted using the INVEST Habitat Risk Assessment (HRA) model to determine which habitat pixels[2] were at such high risk from stressors that they likely are not providing ecosystem services. Several SAC meetings were held in Phase 1 to obtain feedback about the habitat risk information and scenarios. The overlap analysis incorporates activities and stressors such as recreational boating, oyster aquaculture, moorings, docks, dredging, tidal restrictions, hardened shoreline, roads, recreational oyster harvesting, and a simple measure of water quality based on light attenuation. Spatial stressors overlapping with the habitats help determine whether pixels of habitat are too stressed to execute their ecosystem function and provide benefits to people. These highly stressed habitat pixels were removed from the total habitat acreage to determine current conditions related to ecosystem services provided by the three key habitats.

The Current Conditions analysis presents an "MRI of the Great Bay Estuary" because it highlights current spatial stressors and habitat risk. It also sets the baseline for habitat area, habitat stressors (such as moorings and docks), and current activities that may benefit from habitats and impact them (such as recreational boating). The project team uses this baseline to map out hypothetical future scenarios that depict habitat area. Table 1 summarizes current conditions for the three key habitats.

Table 1
Acres of Key Habitats for Current Conditions Scenario (2012/2013)

Key Habitat	Acres
Eelgrass	1,878
Salt marsh	1,804
Low marsh	*561*
High marsh	*1,243*
Oyster beds	137
Oyster bed area open for recreational harvest	*94*
Permitted area for oyster aquaculture [a]	38

[a] Habitat risk was not assessed for oyster aquaculture

[2] The habitat risk assessment was performed using a GIS-based modeling effort. A 'pixel' in this context refers to 100 square meters or approximately 1,000 square feet.

3.2 Future Scenarios

This project developed two hypothetical future scenarios in a multi-stakeholder process using data and information from scientific literature, expert and stakeholder knowledge and informed opinions, and existing spatial datasets. The scenarios are intended to demonstrate two plausible extremes; a scenario where habitats and their benefits are lost and a scenario where habitats and their benefits are gained and sustained. The scenarios are hypothetical, intended to depict two ends of a spectrum of possibilities rather management goals or desired and undesired futures. The scenarios serve to help tell the story of what the Great Bay Estuary could look like and how that could affect people who benefit from it in a not-so-distant future.

3.2.1 Lose Habitats & Benefits

This hypothetical scenario depicts eelgrass, oyster, and saltmarsh area in 2025 if conditions and management result in habitat loss. Water pollution intensifies and no active habitat restoration takes place. This scenario depicts a future where structures like shoreline armoring, docks, and mooring fields do not avoid existing habitats. Activities, including oyster aquaculture, recreational oyster harvesting, and recreational boating, intensify, but do not consider the location of existing and possible future habitat. Oyster aquaculture siting is limited to areas that were open for harvest in 2013, since water quality has not improved enough to result in new areas open to harvest. This scenario assumes that sea level rises two to three inches, resulting in some salt marsh migration. It is important to note that salt marshes are expected to face a tipping point in migration potential if sea level rise accelerates into 2075 and 2100, however, the timeframe for these future scenarios does not capture the potential detrimental impacts of sea-level rise on salt marshes.

3.2.2 Gain & Sustain Habitats & Benefits

This hypothetical scenario depicts eelgrass, oyster beds, and saltmarsh area in 2025 if conditions and management result in a significant expansion of habitat and improvement in habitat function. This scenario assumes that water pollution vastly improves due to new regulations and programs that reduce point and non-point source pollution. As a result, eelgrass recovers beyond the 1996 extent; though areas differ slightly. Significant oyster restoration takes place within the Great Bay channel, avoiding impacts to eelgrass. Oyster aquaculture expands into newly opened growing areas that are opened as water quality improves. Aquaculture siting continues to avoid eelgrass areas. Recreational boating intensifies however, clear markings through the Great Bay channel result in less low tide boating impacts to eelgrass beds. Moorings are sited in the same locations as current conditions, but are all changed to habitat-friendly equipment. Armored shorelines on public and conservation lands are removed along with a few other key tidal restrictions. Recreational shellfish beds recover to 1980's levels as a result of good management and increased spat in the estuary from restoration and aquaculture. This scenario assumes that sea level rises two to three inches resulting in some saltmarsh migration upland but general persistence of low marsh. Once again, it is important to note that salt marshes are expected to face a tipping point in migration potential if sea level rise accelerates into 2075 and 2100, however, the timeframe for these future scenarios does not capture the potential detrimental impacts of sea-level rise on salt marshes.

3.3 Habitat Risk Assessment Modeling

A spatial overlap analysis was conducted using the INVEST Habitat Risk Assessment model to determine how habitats may change in the future. The analysis uses the current conditions as the starting point and then models changes from that starting point to the two future scenarios taking into account the details that define each future scenario; these details are summarized in Section 3.2 above and detailed in

Appendix B. The overlap analysis incorporates activities and stressors like recreational boating, oyster aquaculture, moorings, docks, dredging, armored shoreline, roads, recreational oyster harvesting, and a simple measure of water quality based on light attenuation. The future scenarios assume that most of these activities and stressors have changed in some way in the time between the Current Conditions analysis and in the future scenarios. The two scenarios were set in the year 2025 in order to focus on a not-too-distant-future that is relevant for planning, monitoring, and restoration and conservation goals. Both scenarios assume an increase in human use of the Great Bay Estuary as well as two to three inches of sea-level rise.

The results of the habitat risk assessment modeling appear in the Figure 5, Figure 6, and Table 2. Additional methods and results are provided in more detail in this section and in Appendix B. Figure 5 summarizes the results of the analysis at the habitat level showing acres for each habitat for the current and two future scenarios. Table 2 summarizes the numbers again for the two future scenarios, but adds in sub-habitats (low and high marsh, etc.) and calculates the difference between the two future scenarios. For economic valuation purposes, the difference between the two future scenarios represents a key parameter; economic valuation is applied to the difference in acres. Figure 6 provides a graphical representation of the difference.

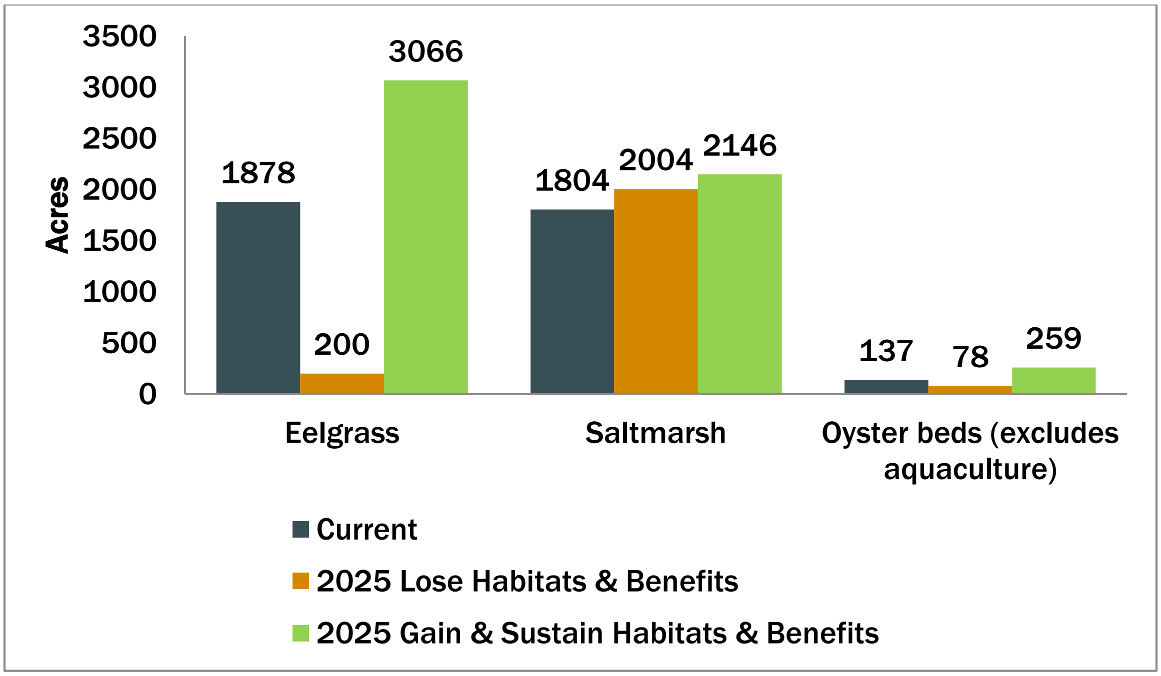


Figure 5
Habitat Risk Assessment Results: Acreage of Habitats for Current Conditions and Two Future Scenarios

Table 2
Acres of Key Habitats for Two Scenarios and Difference Between Two Scenarios in 2025

Key habitat	Lose Habitats & Benefits Scenario	Gain & Sustain Habitats & Benefits Scenario	Difference Between Two Scenarios
Eelgrass	200	3,066	2,866
Salt marsh	2,004	2,146	142
low marsh	*729*	*783*	*54*
high marsh	*1,275*	*1,363*	*88*
Oyster beds	78	259	181
Oyster bed area open for recreational harvest	*34*	*151*	*117*
Permitted area for oyster aquaculture [a]	106	139	33

[a] Habitat risk was not assessed for oyster aquaculture

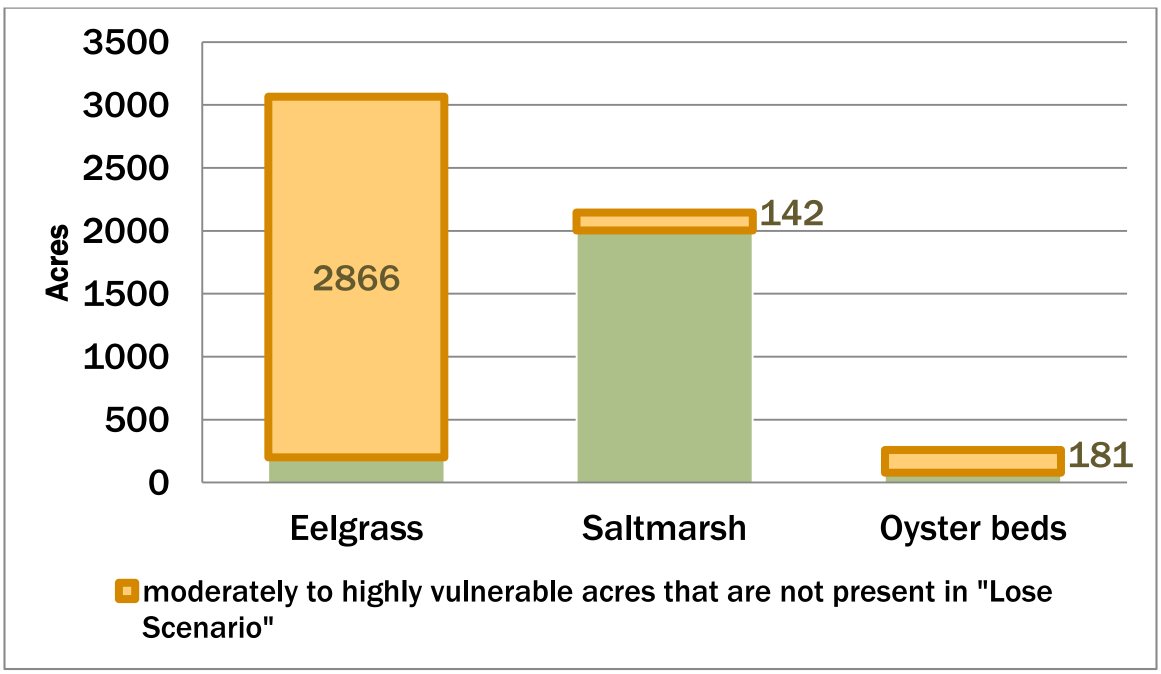


Figure 6
Difference in Acreage Between Two Future Scenarios

3.4 Spatial Analysis

This section presents the spatial distribution of the acreage amounts presented above. The spatial results from the scenario analysis allow us to identify the following relevant information for the time between now and the year 2025:

- **Vulnerable Habitat Areas:** the existing and potential habitat areas that are **most vulnerable** to the multiple stressors evaluated and therefore most likely to contribute to a loss of habitat-specific ecosystem services

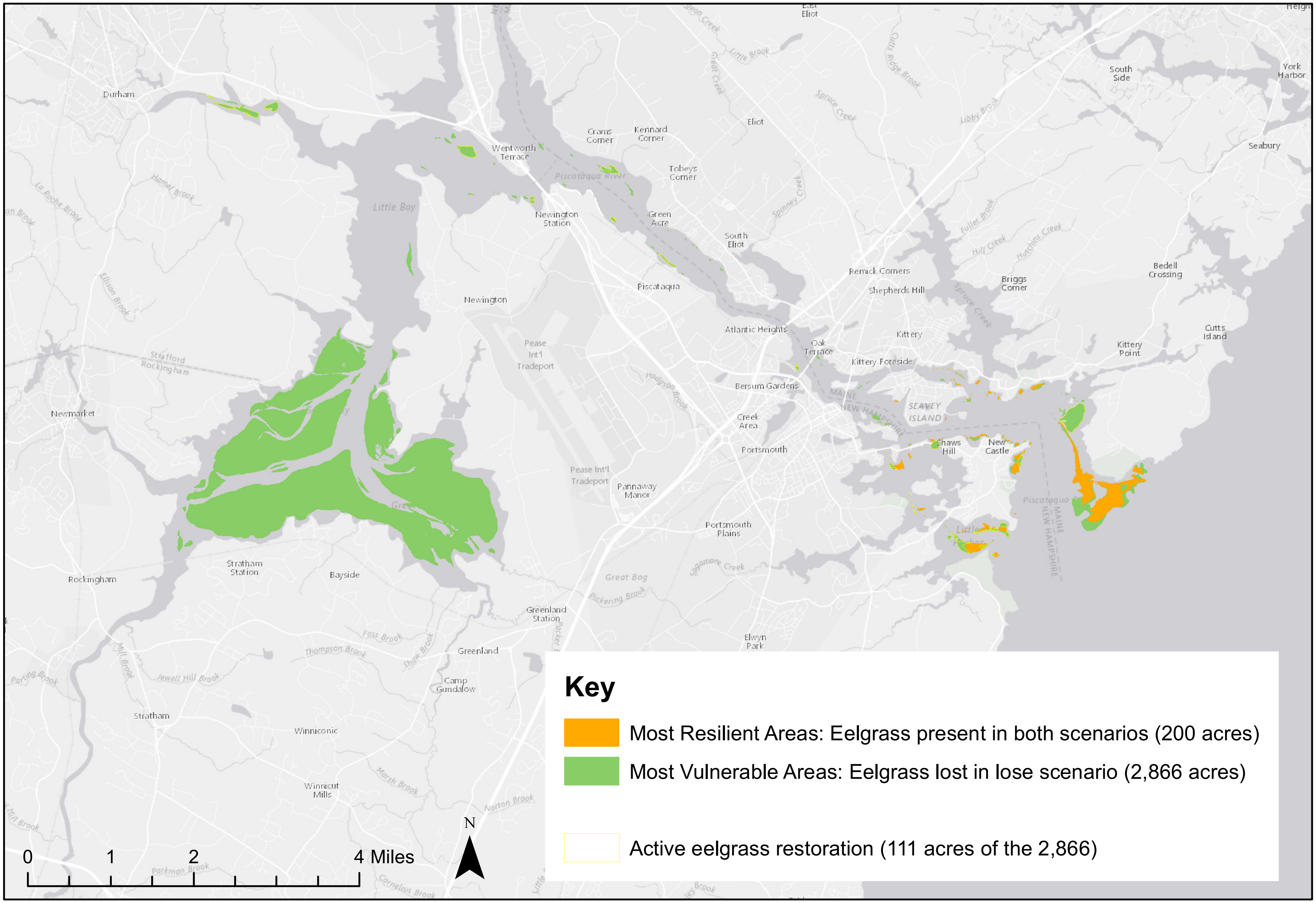
AND

- **Resilient Habitat Areas:** the existing habitat areas that are least vulnerable to the multiple stressors evaluated and therefore most likely to continue providing ecosystem services

Figure 7 through Figure 9 provide maps showing the potential 2025 habitat areas for each key habitat type. The vulnerable areas represent habitat that could be present in 2025 under the Gain & Sustain Habitats & Benefits scenario conditions, but that are most vulnerable to loss or unrealized habitat (and therefore loss or unrealized ecosystem services provided by those habitats) by the year 2025. They also show the existing habitat areas that are least vulnerable to loss or most likely to be that habitat type by 2025.

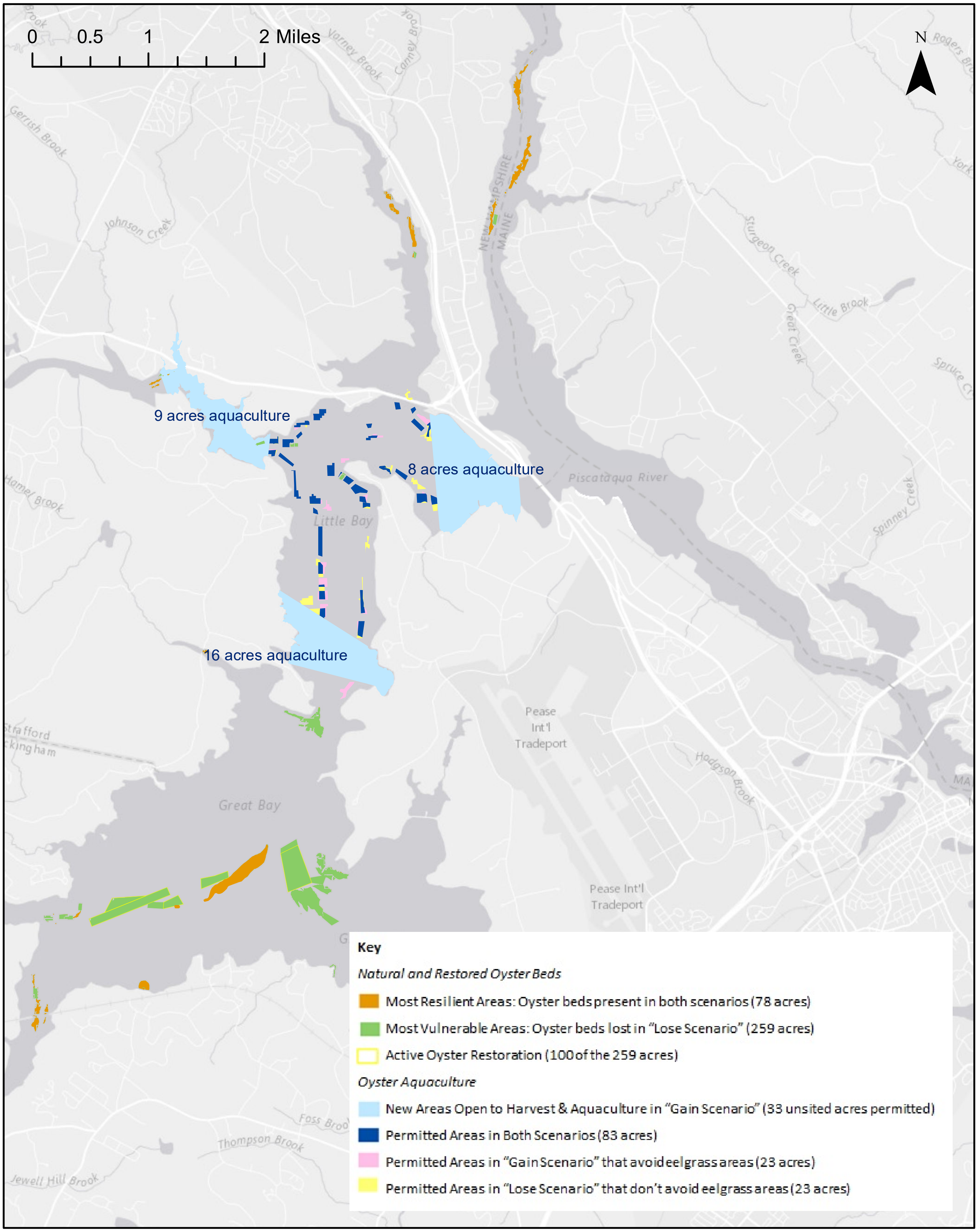
Figure 7: Habitat Risk Assessment for Eelgrass, 2025

Vulnerable and Resilient Eelgrass Areas in 2025



Map produced for Great Bay Ecosystem Services Assessment by Kirsten Howard, NHDES Coastal Program, 10-2016

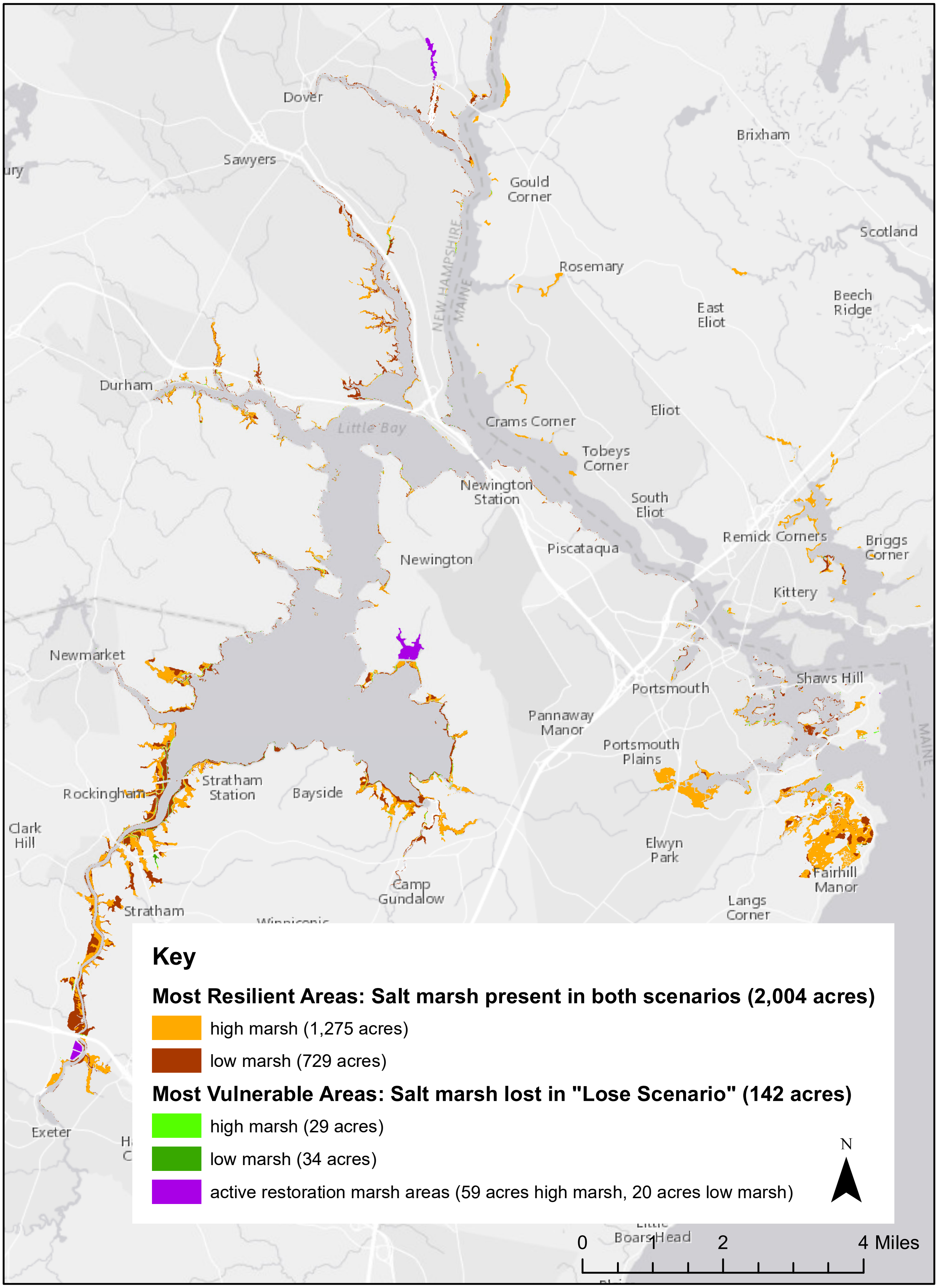
Figure 8: Habitat Risk Assessment for Oyster Beds, 2025
Vulnerable and Resilient Natural Oyster Bed Areas and Hypothetical Oyster Aquaculture in 2025



Map produced for Great Bay Ecosystem Services Assessment by Kirsten Howard, NHDES Coastal Program, 10-2016

Figure 9: Habitat Risk Assessment for Eelgrass, 2025

Vulnerable and Resilient Salt Marsh Areas in 2025



Map produced for Great Bay Ecosystem Services Assessment
by Kirsten Howard, NHDES Coastal Program, 10-2016

4 Phase 2: Ecosystem Service Valuation

This section summarizes the work done by the Project Team to estimate the value of the ecosystem services stemming from the changes modeled in the Phase 1 Habitat Risk Assessment. The section begins by providing background information on economic valuation (Section 4.1) and discussing the approach used by the Project Team in this work (Section 4.2; benefit transfer). Section 4.3 then summarizes the estimates that were developed for the GBESA.

4.1 Understanding Economic Valuation

Goods and services that are bought and sold in a market setting have well-defined values that are dictated by supply and demand forces. For example, the prices of many seafood dishes at restaurants fluctuate over the year as the price for the fish being used fluctuates based on supply and demand. The same is not true, however, for goods that do not have well-defined markets such as clean air or water. In the extreme, these "non-market" goods can be thought of as "public goods". Public goods have two key characteristics:

- Non-rivalry: when one person "consumes" some of the good, the amount available for others is not reduced; for example, someone's enjoyment (consumption) of the view of a pristine salt marsh does not reduce the ability of others to enjoy the view.
- Non-excludability: when the good is provided, it is not possible to exclude people from consuming it; for example, clean air from reduced pollution can be enjoyed by all who breathe.

The goods and services being valued under this project cover both market and public goods, as well as some in-between cases. For example, commercial fishing results in a marketable good (fish). On the other hand, the existence of each habitat represents a public good, it is not non-rival and non-excludable.

"Economic value" is defined as the amount that consumers of a good or service are willing to pay for that good or service. For goods and services with well-functioning markets, the market price is a measure of the willingness to pay (WTP) for that good or service. For non-market goods, economists have devised a number of methods to estimate WTP. A popular set of approaches for non-market goods and services are referred to as "stated preference" approaches. In stated preference approaches, economists develop surveys that ask questions that can be used to determine how much consumers would be willing to pay for the non-market good. Although not without controversy, these methods have been used for several decades and been shown to generate reliable and valid estimates (Haab and McConnell, 2002). ERG did not directly perform a stated preference approach for this project, but in many cases this project used the results from prior studies which did. This approach is referred to as "benefit transfer"; that is, estimates from other studies focused on similar areas are used as a basis for estimating economic values for Great Bay. This is described this in more detail in the section that follows.

The Phase 1 HRA and scenario development resulted in estimates of the number of acres in 2015 (Current Conditions scenario), the number of acres under the "Gain and Sustain" scenario in 2025, and the number of acres under the "Lose Habitats" scenario. For purposes of economic valuation, the differences in the number of acres for each habitat in 2025 are the sources of value. Figure 10 provides a graphical depiction of this situation. The Phase 1 scenario development provided an estimate of the number of acres in the Current Conditions scenario. Each future scenario then results in a change in those starting acres over time with an estimate for each scenario in 2025 with the Gain and Sustain naturally having a larger number of acres compared to the Lose Habitats scenario in 2025.[3] The economic values estimated in this report are based on the difference in acres between the Gain and Sustain and the Lose Habitats scenarios in 2025. Figure 10 depicts the Lose Habitats scenario as increasing line over time; however, this could easily also be depicted as a declining line over time. The key point in the figure is that the source of economic value of the difference between the acres in 2025.

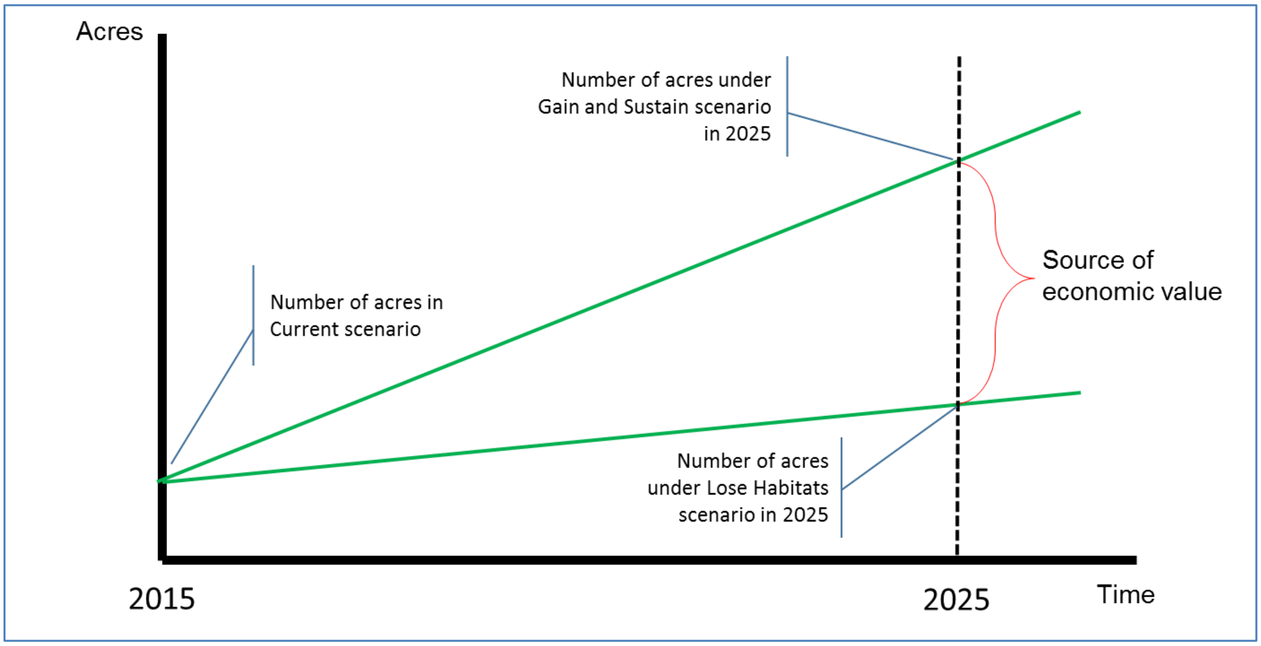


Figure 10
Source of Economic Value in Habitat Risk Modeling

There are, however, two shortcomings to this approach. First, the valuation exercise is not estimating the value for differences in acres between 2015 and 2025; the approach only focuses on the difference in acres in 2025. Second, in providing estimates in the report, the values are phrased as "annual" values moving forward from 2025; in reality, the difference in acres between the two scenarios will only increase after 2025, making the annual estimate an under-estimate of post-2025 values.

4.2 Approach for Valuing Changes to Great Bay: Benefit Transfer

As noted, ERG used benefit transfer methods to develop estimates of the economic value stemming from potential changes to three habitats (eelgrass, oyster beds, and salt marshes) in Great Bay. Benefit transfer involves taking value estimates from a "study site" where time and effort was spent to develop valid estimates and applying those estimates to a "policy site" where estimates are not available; in this project, the Great Bay Estuary is the policy site. Benefit transfers offer the ability to develop estimates of the value of potential improvements at significantly less cost (and time) than developing primary estimates. Valid and reliable application of benefit transfer methods, however, requires relying on

[3] The figure depicts the increase in acres over time as linear which is a simplification.

economic expertise in both identifying relevant estimates to use and adapting the relevant estimates to the policy site. In fact, the validity and ultimately the usefulness of the resulting economic value estimate hinges on the application of economic expertise.

In transferring the estimates from study sites, it is necessary to adjust the estimates. One basic adjustment that almost always needs to be made is for the change in price levels over time (inflation) and to adjust for differences in regional prices (i.e., adjust for the prices in New Hampshire relative to the area where the source estimates come from). In most cases, ERG took the values estimated in other studies, adjusted for temporal and regional differences in prices, and applied those to Great Bay. Additionally, the Project Team modeled the change in the number of *acres* of each habitat; thus, it was necessary to find studies that estimated values in terms of the number of acres or to be able to translate the estimate to a per-acre basis. Appendix D provides guidelines and a process for applying benefits transfers developed under another project.

4.3 Estimated Values for Changes to Great Bay in the Future

This section provides estimates of the economic values associated with improved management under the Gain and Sustain Habitats scenario compared to the Lose Habitats scenario. During the November 2016 SAC meeting (see Appendix C), stakeholders assisted the Project Team to identify ecosystem services to focus on. These included:

- Recreational fishing
- Recreational oyster harvesting
- Commercial fishing
- Carbon sequestration
- Nitrogen removal

As the Project Team began to assess the ecosystem services following that meeting, the Team added in existence value to the list of services based on the comments from the stakeholders during the November meeting. Additionally, the results of the April 2016 SAC meeting resulted in adding in commercial oyster aquaculture.

4.3.1 Existence Value

As the name implies, existence value reflects the value that people or households place on knowing that a specific environmental resource exists. These values are generally considered a “non-use” value; that is, the value that someone would place on a resource even though they do not expect to use it. ERG used existence values estimated from a study of the Peconic Estuary System (PES) on Long Island in the mid-1990s (Opaluch et al., 1999). To estimate these values, the study asked PES residents and tourists about the existence of environmental amenities (including salt marshes, eelgrass, and shellfish beds) in the PES. Given the survey included residents and tourists to the PES, those that provided responses to the survey probably used the resources or could reasonably be expected to use or enjoy the resources. That is, the estimated values must reflect some use value. In summary, the values ERG used for existence value reflect households’ annual willingness to pay for the existence and potential use of salt marshes, eelgrass, and shellfish beds on a per-acre basis. The PES study resulted in the following existence value estimates:

- $0.066 per household per year for salt marshes
- $0.037 per household per year for oyster beds
- $0.082 per household per year for eelgrass

The survey was conducted in 1996; ERG updated these values using the rate of inflation in the New York City area between 1996 and 2015 (56.1 percent) using BLS Consumer Price Index data. Next, ERG adjusted for regional price differences by comparing the rate of inflation in the New York area to the rate in the New Hampshire area;[4] this resulted in setting the New Hampshire area value at 95.3 percent of the New York City area value for 2016 for each estimated existence value.

Next, ERG determined the appropriate number of households to use in calculating the totals. Plymouth State University (PSU) performed a state-wide survey (Rogers et al., 2014) in 2013 that included an oversample of towns in the Piscataqua Region Watershed;[5] ERG applied the existence value estimates to households in the oversampled towns. Based on U.S. Census Bureau data reported by the state of New Hampshire this was 114,959 households.

Table 3 summarizes ERG's estimates for existence value for the Great Bay Estuary. The value per acre per year is calculated by multiplying adjusted values estimated from the PES study by the number of households in the oversampled towns from PSU survey. The increased number of acres reflects the difference between the Gain and Sustain scenario and the Lose Habitats scenario in 2025. Across all three habitats, total estimated existence value for changes in 2025 was $42.5 million in 2015 dollars. As can be seen in the table, approximately 94 percent of that stems from the increased acres in eelgrass combined with a higher per-acre value for the existence of eelgrass.

Table 3 - Existence Value Estimates Based on the Difference Between the Number of Acres in the Gain and Sustain and Lose Habitats Scenarios in 2025

Ecosystem	Value per acre/year	Acres [a]	Total Value
Salt Marshes	$11,285 [a]	142	$1,602,470
Oysters	$6,327	117	$740,259
Eelgrass	$14,021	2,866	$40,184,186
TOTAL	-	-	**$42,526,915**

[a] This is the difference in acres between the Gain and Sustain scenario and the Lose Habitats scenario in 2025.

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[4] New Hampshire is not included as a separate area in the BLS CPI data so ERG used Northeast Size Class B/C data to proxy the change in New Hampshire.

[5] The towns in the Piscataqua Region watershed were oversampled to allow for collecting more detailed information from people in the watershed area. Since this watershed contained Great Bay, ERG felt that this area was an appropriate area to use for applying the existence value estimates which are reflective of how residents value the environmental amenities.

4.3.2 Recreational Fishing

Improved water quality in Great Bay should lead to an increase in the use of the Bay by recreational fishermen. Economists estimate the value of increased recreational fishing by first estimating the increased number of trips that would occur due to better water quality and then estimating what recreational anglers would be willing to pay for those additional trips. ERG used a prior study to estimate the increased number of trips (per person) that recreational fishermen would take to the Bay and the value they would be willing to pay for increased use of the Bay associated with better water quality (Englin et al., 1997). The study used data from the 1989 survey of Freshwater Recreational Anglers and combined those data with data on lake-level water quality from the EPA Eastern Lakes Survey for the same time period. This allowed the study to estimate a relationship between water quality and the number of trips that anglers take to specific water bodies. The study used two water quality variables: the level of dissolved oxygen (DO) and turbidity. ERG used an assumed improvement in DO to measure improvements under the Gain and Sustain scenario in the NHCP modeling effort.[6] Data from the NERRS data portal[7] indicated that average DO in Great Bay (at one monitoring station) was 8 mg/L in 2015. ERG then calculated the increased number of recreational fishing trips to Great Bay based on improvements from 8 mg/L DO to 10 mg/L and 12 mg/L. As it turns out, turbidity is a key factor in explaining the number of fishing trips to a water body in the model used; therefore, ERG performed the calculations for the increased number of trips at 2, 4, and 5 Nephelometric Turbidity Units (NTU).[8] ERG was unable to identify good information on the number of anglers in Great Bay, so the increased number of trips was phrased in terms of the number of trips *per 1,000 anglers* per year.

ERG's estimates of the increased number of trips are provided in Table 4. The results in the table highlight the profound effect that turbidity has on fishing trip estimates in this model. The study used also provided an estimate of the amount that recreational anglers were willing to pay for each trip they took; after updating the value for inflation, the estimated per trip willingness to pay value was of $89.77 in 2015 dollars. Table 4 provides the value of the increased number of trips (per 1,000 anglers again).

ERG's assessment of these estimates, however, is that they provide little insights into the added value associated with increased recreational fishing in Great Bay due to improved water quality. First, the estimates are highly sensitive to turbidity levels which is most likely due to the estimate being based on freshwater recreational fishing. Second, based on discussion with stakeholders on this project, ERG expects the lower levels of turbidity, and hence the higher economic values, are probably not realistic for Great Bay. Thus, these estimate have been included for context, but are not recommended for further use.

[6] It should be noted that NHCP has not modeled changes in DO or turbidity; thus, the report only present estimates for different levels of DO and turbidity based on the selected source study.
[7] http://cdmo.baruch.sc.edu/
[8] The NERRS data portal also indicated that the average level of turbidity in Great Bay in 2015 at the monitoring station ERG used was 5 NTU.

Table 4 - Increased Number of Annual Fishing Trips and Economic Value of the Increased Number of Trips per 1,000 Anglers Who Fish in Great Bay Associated with an Increase in Dissolved Oxygen (DO) from Current Levels (~8 mg/L) to Selected Higher Levels of DO for Three Levels of Turbidity

Assumed Improved Level of Dissolved Oxygen (Base = 8 mg/L)	Turbidity Levels					
	2 NTU		4 NTU		5 NTU	
	Increased Number of Trips	Value of Trips ($2015)	Increased Number of Trips	Value of Trips ($2015)	Increased Number of Trips	Value of Trips ($2015)
10 mg/L	229	$20,545	13	$606	2	$107
12 mg/L	1,535	$72,171	43	$2,015	8	$355

NTU = Nephelometric Turbidity Units

4.3.3 Recreational Oyster Harvesting

NHCP has estimated that the Gain and Sustain scenario will result in more acres of oyster beds compared to the Lose Habitats scenario in 2025. The difference between the two scenarios will provide additional opportunities for recreational harvesting of oysters. This will have value to those who partake in recreational harvesting. ERG estimated these values by first estimating the increased in the number of oysters in Great Bay under the Gain and Sustain scenario compared to the Lose Habitats scenario. ERG then estimated an increase in the number of licenses that would be sold due to the increased number of oysters. Finally, ERG applied a per license willingness to pay value to the increased number of license taken from a prior study.

Step 1 – Estimate the increased oysters in Great Bay. To estimate the number of increased oysters in Great Bay, ERG used data from PREP's environmental data report (PREP, 2012). Data in that report provide estimates of adult oyster density (per m^2) at six locations within Great Bay from 1993 to 2011. The report also identifies PREP's target density levels for each area and the acres of oyster beds in each area. ERG calculated a weighted average density for PREP's targeted densities for Great Bay by weighting the density targets for each area with the number of acres in the area; this resulted in a targeted density of 42.94 oysters per square meter, or 173,776 oysters per acre. ERG also used the data from the PREP report to calculate a median value for oyster density. For each area ERG calculated the median value between 1993 and 2011 and then calculated a weighted average (using acres as the weighting again) of the median values; this resulted in an estimate of 8.43 oysters per square meter, or 34,108 oyster per acre. The PREP target value (173,776 oysters per acre) and the median-based estimate (34,108 oysters per acre) are used to proxy the potential number of oysters in Great Bay under the Gain and Sustain scenario relative to the Lose Habitats scenario (Table 2). NHCP has estimated that 117 additional acres of recreational oyster beds would be open in 2025 under the Gain and Sustain scenario compared to the Lose Habitats scenario. The additional 117 acres combined with the values estimated in the paragraph result in an estimated 20,331,801 oysters if the PREP target densities are met by 2025 and 3,990,677 oysters if the Bay generates densities closer to the median densities between 1993 and 2011. The next step is to translate these increased number of oysters into an increase in the number of licenses.

Table 5 – Source Data for Estimating the Increased Number of Oysters for Recreational Harvesting in Great Bay

Category	Adams Point	Nannie Island	Oyster River	Piscataqua River	Squamscot t River	Woodman Point
Acres of oyster beds	4	37.3	1.8	12.8	1.7	6.6
PREP density target (adult oysters per m^2)	38	50	29	20	9.3	63
Median density between 1993 and 2011 (adult oysters per m^2)	11.2	8	28.9	1.85	28.4	11.2

Source: PREP, 2012.

Step 2 – Estimate the increase in recreation oyster harvesting licenses from an increase in oysters. NHCP provided ERG with data on the number of shellfish licenses sold by NH Fish and Game (NH F&G) from 1975 to 2015 and the number of oysters harvested from 1994 to 2011.[9] ERG used these data to calculate the relationship between oyster licenses and oysters harvested using regression analysis. The resulting regression model related the number of licenses to the number of oysters harvested and the square of the number of oysters harvested. The estimated model was:

$$L = 178.13 + 0.08 \times O - 2.85e\text{-}6 \times O^2$$
$$(2.05) \quad (1.69) \qquad (-0.79)$$

where L stands for licenses, O stands for oysters (measured in 1,000s), and the values in parentheses underneath the equation are the *t*-value for testing for statistical significance. Using the estimated increase in the number of oysters from Step 1 above, the PREP target density-based estimate would result in 631 new licenses and the median-based estimate would result in 453 new licenses.

Step 3 – Estimating the economic value of new licenses. ERG used a study from 2004 on Cape Cod which estimated that people were willing to pay $39 (per year) for shellfish licenses (Damery and Allen, 2004); ERG updated that value to value of $52.26 to reflect inflation using the Consumer Price Index from BLS. The estimated 631 new shellfish licenses associated with meeting PREP's density targets would be valued at $32,998 in 2025. If densities are closer to the historical median values in the Bay the estimated 453 new licenses would be valued at $23,671 in 2025.

4.3.4 Commercial Oyster Aquaculture

The habitat risk modeling performed by NHCP indicated that 33 new acres would be open to commercial aquaculture farms under the Gain and Sustain scenario compared to the Lose Habitats scenario. NHCP provided ERG with data on the numbers of permitted acres of oyster aquaculture, the number of acres harvested, and the total number of oyster harvested from those acres for 2013-2015. Those data, along with the number of oyster per harvested acre appear in Table 6.

[9] Both data sources originated from the NH F&G.

Table 6
Permitted and Harvester Acres for Oyster Aquaculture, Number of Oysters Harvested and Per-Acre Productivity

Year	Acres Permitted	Number of Acres Harvested (Percent of Permitted)	Totals Oysters Harvested	Oysters Harvested Per Acre
2013	29	19 (66%)	81,274	4,278
2014	38	22 (58%)	164,965	7,498
2015	50	25 (50%)	207,024	8,281

Source: Data provided by NH F&G to NHCP for this project.

ERG used the data in Table 6 to estimate the commercial oyster aquaculture harvest in 2025. First, ERG assumed that 80 percent of the 33 new acres (26.4 acres) would be harvested. Second, ERG used the per-acre productivity from 2015 (8,281 oysters per acre) as a proxy for potential productivity in 2025. Finally, the New Hampshire Fish and Game department indicated that recent oyster prices have been in the 60 – 65 cents per oyster range. Thus, using an estimated productivity of 8,281 oyster per acres, assuming 80 percent of the new acres are harvested, and the price range of 60 – 65 cents per oyster, the new acres would generate between $131,171 and $142,102 annually in revenues.

4.3.5 Commercial Fishing

The increased number of acres of salt marsh and eelgrass under the Gain and Sustain scenario compared to the Lose Habitats scenario will provide nursery habitat and forage area for commercial fish species, resulting in a larger amount of commercial fishing catch under the Gain and Sustain scenario in the future. ERG's approach to valuing these improvements was to use a "trophic transfer" calculation (McCay et al., 2003; Kneib, 2003). A tropic transfer calculation involves first identifying the primary productivity of an ecosystem and then determining the amount of that productivity that is lost at successive trophic levels. This is done up to the point at which a trophic level is reached that reflects a marketable commodity. This approach has been used before to value changes in fishery productivity (EPA, 2011).

For salt marshes, ERG started with the primary productivity of marsh grasses (500 grams of dry weight per square meter per year (g DW m^{-2} yr^{-1}) in New England marshes) and benthic microalgal production (106 g DW m^{-2} yr^{-1} in New England marshes) (McCay et al., 2003). At each successive trophic level, some of this productivity is lost. At the tropic level associated with commercial fish species, only 0.16 percent of the total primary and benthic microalgal production remains (Kneib, 2003). Assuming dry weight is 22 percent of wet weight[10] and translating from grams to kilograms and from square meters to acres, salt marshes generate 17.8 kg wet weight (WW) per acre per year that reaches the market. To place a value on this amount, ERG downloaded landings and total revenue data for NH from the National Marine Fisheries Service (NMFS) database by species for 2010-2014. ERG calculated the percentage that each species contributed to total landings and used those percentages to calculate a weighted average price for NH landings. This is resulted in a value of $4.64 per kg. In calculating the productivity of marshes, ERG used only the low marsh increase of 54 acres (see Table 2). Thus, the 54-acre difference in low salt marsh

[10] This ratio was used in each study reviewed related to tropic transfers.

acres between the Gain and Sustain scenario and the Lose Habitats scenario in the ecosystem modeling would result in an increase value of $4,473 per year (2015 dollars) to commercial fisheries, a relatively low value. These calculations are summarized in Table 7.

The considerations for eelgrass are more complex and include considerations on export of productivity and a comparison of primary to benthic faunal production. The studies ERG reviewed, however, use benthic faunal production (175 g DW m^{-2} yr^{-1}) as the starting point with 4 percent of that productivity reaching a marketable trophic level (McCay et al., 2003; Kneib, 2003). Thus, eelgrass results in 128.8 kg WW per acre per year. Using the same composite price per kg of $4.64 results in a value of $1.7 million annually for the 2,866-acre difference in eelgrass between the two future scenarios. These calculations are summarized in Table 7.

Table 7
Trophic Transfer Calculations for the Difference Between the Number of Acres in the Gain and Sustain and Lose Habitats Scenarios for Salt Marsh and Eelgrass in 2025

Habitat	Acres [a]	Base Productivity Value (g DW m^{-2} yr^{-1})	Transfer Rate to market	Net transfer to market (kg WW $acre^{-1}$ yr^{-1})	Value per kg (composite price)	Annual value ($2015)
Salt marshes	54	606	0.16%	17.8	$4.64	$4,473
Eelgrass	2866	175	4.0%	128.8	$4.64	$1,714,007

[a] This is the difference in acres between the Gain and Sustain scenario and the Lose Habitats scenario in 2025.

4.3.6 Carbon Sequestration

Salt marshes and eelgrass are both capable of sequestering carbon. Thus, the increased acres of salt marsh, eelgrass, and oyster beds under the Gain and Sustain scenario compared to the Lose Habitats scenario will lead to an increase in the amount carbon sequestration in Great Bay. These benefits, however, can be considered global benefits since reducing carbon in the atmosphere benefits individuals well beyond the borders of New Hampshire.

To estimate the carbon sequestration benefits, ERG first calculated the additional carbon that could potentially be sequestered in the additional acres of marsh and eelgrass in Great Bay under the Gain and Sustain scenario. For salt marshes, ERG used three estimates:[11]

- 116 g per m^2 per year (0.471 metric tons (MT) per acre per year) (Ouyang and Lee, 2014)
- 218 g per m^2 per year (0.882 MT per acre per year) (McCleod et al., 2011)
- 0.91 MT per hectare per year (2.25 MT per acre per year) (CEC, 2016)

Each estimate taken from the literature was translated into a MT per acre per year (in parentheses in the bullets above). The first estimate reflects the average value for three salt marshes in Massachusetts reported on in the referenced study. The other two values reflect a global average (218 g per m^2 per year) and a North American average (0.91 MT per hectare per year). For eelgrass, ERG used two estimates from the literature:

[11] The bullet points present the values that were reported in the source studies in the units that were reported. ERG converted all of those to metric tons (MT) per acre per year and present those values in parentheses.

- 138 g per m^2 per year (0.471 MT per acre per year) (McCleod et al., 2011)
- 83 g per m^2 per year (0.882 MT per acre per year) (CEC, 2016)

As with the salt marsh values for the source studies, one reflects a global average (138 g per m^2 per year) and the other a North American average (83 g per m^2 per year). Finally, for oysters, ERG used one value:

- 0.81 MT per hectare per year (0.348 MT per acre per year) (Fishsite, 2009)

The values for salt marshes and eelgrass were applied to the difference in acres between the Gain and Sustain scenario and the Lose Habitats scenario in 2025; for oyster beds, ERG used the difference in acres of recreational beds between the two scenarios plus the total acres opened to commercial aquaculture in 2025 (150 total acres of oyster beds).

Carbon sequestration can be valued using a social cost of carbon (SCC) approach. The SCC measures

> "…the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change." (IWGSCC , 2015)

EPA estimates that the SCC for tons of carbon in 2025 is $46 in 2007 dollars; ERG updated that estimate to $51 in 2015 dollars (IWGSCC, 2015). The estimates for the value of the social cost of carbon appear in Table 8.

Table 8
Social Cost of Carbon Estimates for the Difference Between the Number of Acres in the Gain and Sustain and Lose Habitats Scenarios for Salt Marsh and Eelgrass in 2025

Habitat	Sequestration Rate (MT per acre per year)	Acres [a]	SCC ($2015; value per metric ton)	Total Carbon Sequestered (metric tons)	Total Value ($2015)
Salt Marshes	0.471	142	$51	66.8	$3,408
	0.882			125.3	$6,839
	2.249			319.3	$16,285
Eelgrass	0.558	2,866		1,600.6	$81,629
	0.336			962.7	$49,096
Oyster beds	0.348	150		52.2	$2,662

[a] This is the difference in acres between the Gain and Sustain scenario and the Lose Habitats scenario in 2025.

4.3.7 Nitrogen Removal

Increased acreage of oyster beds, salt marsh, and eelgrass will reduce the amount of Nitrogen in the Great Bay Estuary. Less nitrogen in the water column requires less expenditures on waste water treatment facilities (WWTF) by towns bordering the bay.

A study conducted for the EPA Regional Ecosystem Services Research Program estimates the WWTF cost of nitrogen treatment is between $68 and $77 per pound annually at the 18 municipal facilities currently discharging into GBP (Regional Ecosystem Services Research Program, 2015).[12] An EPA study estimates oysters in the Great Bay may remove 782 pounds of nitrogen per acre per year. Drake et al. (2015) estimate that salt marsh in Massachusetts and Maine may remove between 2.8 and 11.3 grams of nitrogen per meter per year (equivalent to between 25 and 101 pounds of nitrogen per acre per year);[13] ERG's estimates took an average of the two values (63 pounds of nitrogen per acre per year). Cole and Moksnes (2016) estimate that eelgrass removes 12.3 kilograms of nitrogen per hectare per year (equivalent to 67 pounds of nitrogen per acre per year).[14] The resulting estimates appear in Table 9.

Table 9
Economic Value of Nitrogen Removal for the Difference Between the Number of Acres in the Gain and Sustain and Lose Habitats Scenarios in 2025

Habitat	Acres [a]	N Removal Rate (pounds per acre)	Total N Removed (pounds)	Avoided Cost Per Pound ($2015)		Total Value ($2015)	
				Lower	Upper	Lower	Upper
Salt Marshes	142	63	8,946	68	77	$608,328	$688,842
Oysters	150	520	78,000	68	77	$5,304,000	$6,006,000
Eelgrass	2866	67	192,022	68	77	$13,057,496	$14,785,694

[a] This is the difference in acres between the Gain and Sustain scenario and the Lose Habitats scenario in 2025.

4.3.8 Summary of Estimates

Table 10 summarizes the estimated economic values from the sections above.

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[12] "Amortized capital costs plus annual O&M costs were combined to estimate the total annual costs for each treatment level for nitrogen removal. A range of interest rates from 2 to 5 percent were selected to bracket the potential rates for a 20 year bond." Three nitrogen effluent limits were considered: 8 milligrams per liter (mg/l), 5mg/l, and 3mg/l.
[13] High and low estimates based on nitrogen accumulation at two marshes managed with open marsh water management (OMWM) and two marshes that were not at U.S. Fish and Wildlife National Wildlife Refuges (NWRs). Also considered two methods: Cs-137 and Pb-210.
[14] Estimate for eelgrass (Zostera marina) on the Swedish northwest coast.

Table 10
Summary of Economic Valuation Estimates Reflecting Projected Difference in Acres in 2025 Comparing the Gain and Sustain Scenario to the Lose Habitats

Ecosystem Service	Habitat	Estimated Economic Value in 2025 (phrased in 2015 dollars)
Existence value	Salt marshes	$1.6 million
	Eelgrass	$40.2 million
	Oyster beds	$0.7 million
Recreational fishing	All	Variable; depends on turbidity and improvements in dissolved oxygen
Recreational oyster harvesting	Oyster beds	$23,700
Commercial aquaculture	Oyster beds	$131,200 - $142,100
Commercial fishing	Salt marshes	$4,473
	Eelgrass	$1.7 million
Carbon sequestration	Salt marshes	$3,400 - $16,300
	Eelgrass	$49,100 - $81,600
	Oyster beds	$2,700
Nitrogen removal	Salt marshes	$608,300 - $688,800
	Eelgrass	$13.1 million - $14.8 million
	Oyster beds	$5.3 million - $6.0 million

5 Outreach and Communications

The Project Team used input from the April and June 2016 SAC meetings to develop and refine a set of graphics that can be used to convey the estimates that resulted from the work performed under the project. Two types of graphics were developed. First, a graphic reflecting the estimated economic value associated with improvements to commercial fishing was developed (the “map graphic”). The final version of this graphic appears in Figure 11. Second, a graphic was developed that could be used to depict the estimates from other ecosystem services that were considered under the project. This graphic, referred to as the “flow graphic” appears in Figure 12. The flow graphic depicted in Figure 12 highlights existence value; as before, the graphic can be customized to depict estimates for other ecosystem services.

Figure 11
Outreach Graphic Depicting Commercial Fishing Value Estimates for Gulf of Maine ("Map Graphic")

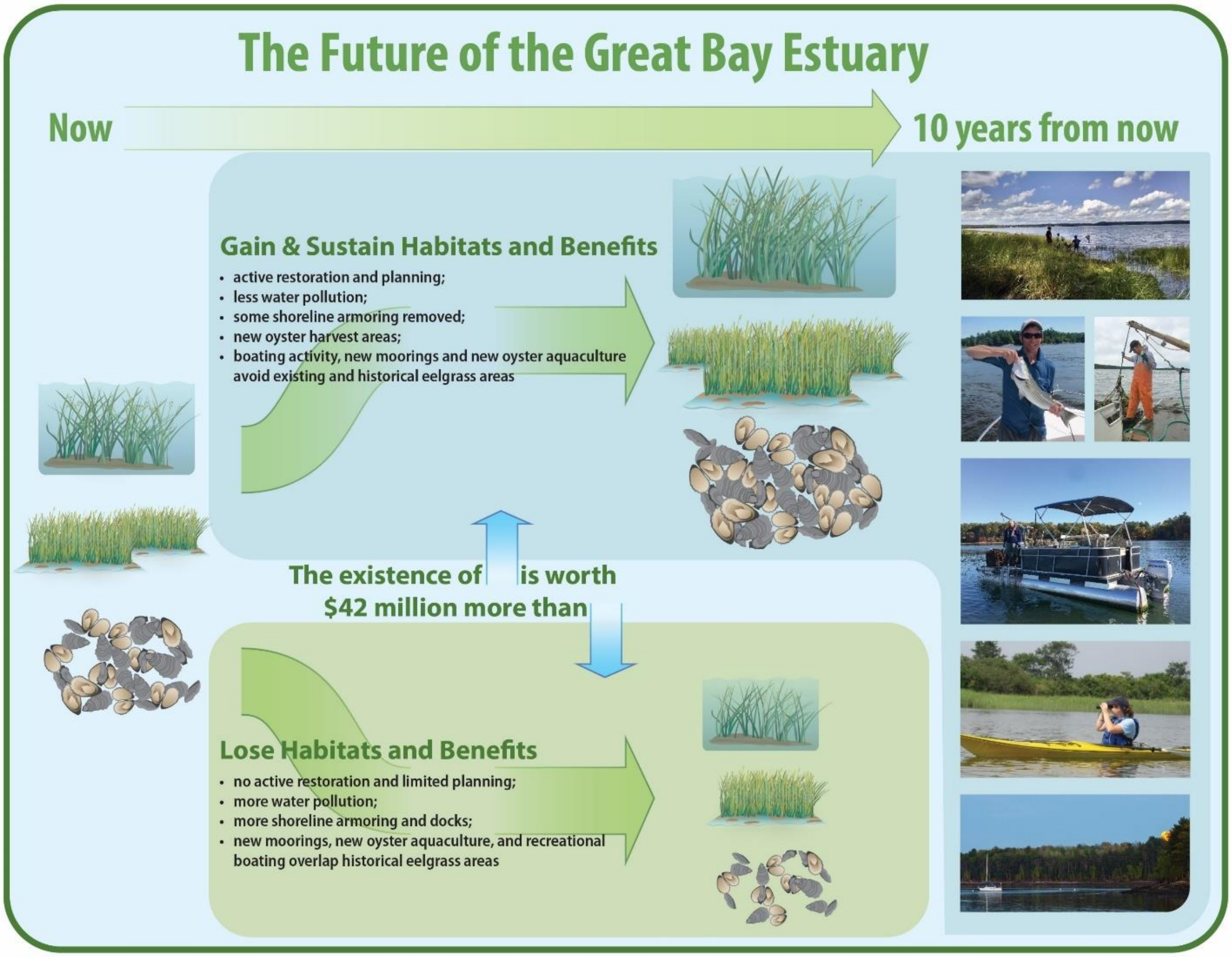

Figure 12
Outreach Graphic Depicting Existence Value Estimates ("Flow Graphic")

6 Recommendations for Transferability

This section provides thoughts on the transferability of the methods used in this project to other National Estuarine Research Reserve sites and other situations in general where ecosystem service assessments could be performed. The items we list in this section include tips and best practices for transferring this approach to others situations, but also lessons learned from this project as well , referencing specific aspects of this project as examples. A key theme that runs through these recommendations is the value of obtaining stakeholder input throughout the project and iteratively incorporating that input into the project work.

- **Develop a clear statement of the management objective that is accepted by stakeholders**. The work in Great Bay benefitted from both a well-defined research question and management objective. This process started with the CCMP developed by PREP (PREP, 2010) and continued through the further development of scenarios used in habitat risk assessment modeling. There were, however, some stakeholders who struggled with how they might use the project outcomes. Thus, a key component of transferring this approach to other situations would be developing a clear management objective and ensure that stakeholders understand the objective and how the results could be used at the outset.
- **Pull in expertise as needed**. The GBESA Project Team continually brought on expertise as needed to fill gaps in capacity and knowledge. First, those who initiated the project obtained a NOAA Coastal Management Fellow to perform the detailed habitat risk assessment modeling. Next, the Project Team partnered with NOAA to bring on expertise in economic valuation and in stakeholder facilitation (ERG). Additionally, the Project Team sought out stakeholders with specific expertise (e.g., eelgrass in Great Bay, etc.) along the way to further inform work; this included having discussions with the UNH JEL and working with the NH Fish & Game Department.
- **Use frequent feedback loops with stakeholders**. The basic flow of this project involved the Project Team meeting with stakeholders, using that meeting as a basis for performing work, and then meeting with the stakeholders again to review the work and move the project forward. This cycle repeated itself throughout the project. This worked well since it allowed the Project Team to keep stakeholders in the loop and to get direction from stakeholders moving forward.
- **Work with stakeholders to define priorities**. The Project Team focused throughout the project on obtaining stakeholder input. This included defining priorities for which ecosystem services to focus on in the economic valuation work. In fact, during the November 2015 SAC meeting under Phase 2 of the project, stakeholders were asked to vote on which ecosystem services to focus on and the remainder of the meeting involved collecting information from stakeholders on those ecosystem services. Since stakeholders defined the priority ecosystem services, the project benefited from immediate buy-in from the stakeholders on the focus of the work.
- **Engage in an iterative process of increasing the awareness between stakeholders and researchers throughout the process**. The project involved a two-way street of increasing the awareness and knowledge of both stakeholders and the researchers. On the one hand, the research team provided information on the research approach and outcomes by providing details on habitat risk modeling and on economic valuation. On the other hand, stakeholders continually provided information and details that the research team could use in developing the analysis. The research team found that the two-way street vastly improved the final product under this

project.

- **Balance the time requirements of stakeholders with the needs of the project**. The Project Team asked stakeholders to attend several meetings over the course of the project. For the most part, many stakeholders were able to attend several meetings. Nevertheless, some could not attend all the meetings. Furthermore, although some information was collected from stakeholders outside the meeting process, the most productive information was obtained during meetings. Thus, a key takeaway from this project is the need to be mindful of stakeholders' time and to find efficient ways of using their time. This project used SAC meetings to allow for interaction between the stakeholders. Nevertheless, the Project Team limited the number of meetings to limit the burden on stakeholder time.
- **Develop outreach with stakeholder needs in mind**. The project involved developing a set of outreach materials that conveyed the results of this work. These outreach materials were developed with stakeholder needs in mind. During the April 2016 SAC meeting, the Project Team discussed the outreach needs with stakeholders, focusing on the audiences and the messages that stakeholders would use. At the June 2016 meeting, the Project Team presented draft versions of the materials and refined them with stakeholders in break-out groups. In the end, the materials developed reflected the needs of stakeholders to ensure maximum usability.
- **Invite someone from another NERR or another area to participate in the project as an observer**. This project had a "transfer representative" among the stakeholders whose role was to observe and participate in the process from an outsider's perspective. This had several benefits. First, it allowed for a new perspective on the work being performed. Second, it provided that person with information on how this type of work would be performed. Finally, it also leads to an increased overall awareness of this type of analysis. Thus, having a NERR (or other area) that is considering performing an ecosystem service assessment in the future participate as an observer in an ongoing one would benefit both the ongoing and the future project.
- **Give time for stakeholders to understand and gain comfort with key project components**. One change that the Project Team would recommend from the process used in this work would be to increase the number of SAC meetings to allow stakeholder more time to "digest" key results. Specifically, in the April 2016 meeting, ERG presented the draft valuation results and then pivoted to a discussion on how to formulate the draft outreach materials. In assessing that meeting, the Project Team felt those two objectives needed to be done separately. The issue was that the stakeholders had little time to "digest" the valuation results before they were asked about how they would use those results. In turn, some of the small group discussions that were focused on how to use the results turned into discussion on what the results meant. The lesson learned is that stakeholder need time to understand and feel comfortable with key project components before moving forward with the work. Implementation of this recommendation, however, needs to take into consideration the recommendation above about balancing the time requirements of stakeholders.

7 Lessons Learned and Next Steps for Great Bay

7.1 Lessons Learned

The GBESA was an exploratory assessment to better understand the ways people benefit from Great Bay Estuary ecosystems and inform decisions to sustainably maximize those benefits while reducing conflict. The project team identified several lessons learned through the GBESA effort.

7.1.1 Stakeholder Engagement

The GBESA stakeholder engagement process was thoughtfully designed and thoroughly executed, particularly the first phase of engagement to design and run the InVEST Habitat Risk Assessment model. Stakeholders benefited from having to collaboratively discuss and agree on key risk factors associated with different Great Bay habitat (see Appendix B). Stakeholders learned about the spatial distribution of habitats and stressors and where conflicts exist as well as where they do not. In the ecosystem services assessment phase of the project, SAC members learned what ecosystem services are and what they aren't. They had to work together to prioritize the most important ecosystem services produced in the Great Bay Estuary and to decide on specific storylines for the future scenarios. They also learned about economic valuation of ecosystem services as well as the strengths and limitations of valuation. Many of these stakeholders are ecological or policy experts who understood the general concept that habitats produce benefits to people, but had limited experience actually selecting valuation methodologies and applying them. As with all complex projects that engage stakeholders, more stakeholder engagement would have likely resulted in additional understanding about the results and their limitations.

7.1.2 Scenarios

The management scenario approach used in the GBESA project produced some valuable insights and created some challenges. The scenario effort was highly dependent on having appropriate spatial datasets in the Great Bay Estuary—for the most part, the datasets were available for this effort, however there were some limitations associated with water quality data and other spatial information. Project partners engaged in a visioning process that forced them to consider best and worst case scenario future conditions for the Great Bay Estuary ecosystems. Some spatial planning questions were addressed throughout this process, including how to site oyster aquaculture in relation to existing or historic eelgrass sites. As the same time, the scenario approach was static, with only two scenarios being considered for a fairly close timeframe of 2025. Some iteration occurred after first drafts of the scenarios were presented, however, because several stressors and uses were altered in each scenario, it was difficult to attribute any change in ecosystem services to one management decision. This resulted in final results that are primarily applicable in communicating about the Great Bay system as a whole.

7.1.3 Valuation

Guidelines and best practices for conducting benefits transfer ecosystem services valuation projects can be found in Appendix D. One critical lesson that the project team learned is that including economic expertise on the team early is important to ensure that the project goal, objectives, and approach for valuation are feasible given data and resource limitations. Additionally, valuation concepts are complicated, therefore repeating them regularly to the project team and stakeholders is important.

7.1.4 Use and Communication of Results

While the assessment results are expected to be used as a communication tool by partner organizations, the assessment likely would have had a greater impact if it had been tied to a specific policy decision context from the beginning of the project. A lack of policy context likely resulted in an analysis that is broad in scale and better suited for communication and education purposes rather than specific management decision-making. At the same time, because the GBESA was removed from the nutrient-related policy issues going on in the Great Bay Estuary, the process allowed partners to take a look at spatial planning options for the area.

Partners agreed that, in particular, they will engage in communication of the existence value results. The graphics created to communicate the project will help to explain the concept to new audiences. However, because of the caveats associated with the valuation results, partners indicated that they still are hesitant to use all of the results with general audiences. In particular, the fact that the valuation results represent a difference in value between two potential future scenarios is an important caveat that complicates the results.

Ultimately, the GBESA lays a solid groundwork for future, more specific valuation work to answer specific decision-relevant questions during an open policy window.

7.2 Next Steps

In reflecting about the GBESA results and outcomes, the project team identified some important next steps for ecosystem services assessment work in Great Bay and elsewhere in coastal New Hampshire.

Digital Coast fellowship project: What's at stake? Understanding and communicating the impact of coastal wetland loss

A fellow working with the National Estuarine Research Reserve Association, the Wells National Estuarine Research Reserve, and the Great Bay National Estuarine Research Reserve is working to understand how different audiences understand ecosystem services information about coastal wetland protection and loss. This effort will draw from information produced by the GBESA to understand if and how the information produced is useful to various potential audiences.

Oyster restoration and aquaculture decision-making

PREP, TNC, and other organizations expect to use the GBESA results to inform ongoing discussions around future oyster restoration sites and oyster aquaculture siting. These conversations are ongoing with the NH Department of Fish & Game, funders, and other stakeholders.

PREP State of the Estuaries Report

PREP expects to use some limited results in the messaging around the State of the Estuaries Report.

The future of ecosystem services assessments in the Great Bay Estuary

The project team felt better informed about both the cost of these types of projects and the information they are capable of producing. In general, there is interest in furthering knowledge about specific ecosystem services in the Great Bay Estuary as well as some hesitation and apprehension about the utility of these approaches—whether they can truly result in better decisions than those that would be made without ecosystem services understanding and information. Partners agreed that economic valuation at a fine resolution is not feasible due to cost.

There are several other ecosystem service valuation efforts going on in coastal New Hampshire and

Maine, including the GBNERR Buffers for the Bay project and a Hampton-Seabrook Estuary project on coastal vulnerability. The partners are interested in comparing the outcomes of these projects to understand if certain processes inform decisions better than others.

According to project partners, the following five efforts present the most promising opportunities for integrating ecosystem services information into planning and decision-making in the Great Bay Estuary and coastal New Hampshire over the longer term:

- habitat restoration planning,
- the Aquatic Resource Mitigation Fund criteria,
- aquaculture permitting,
- mooring siting, and
- carbon sequestration.

Project partners challenged each other to explore the results and use the results to inform future conversations about integrating ecosystem services into program priorities and policy change.

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Appendix A
Project Team and Stakeholder Advisory Committee Membership

Project Team (Phases 1 and 2)

The project team consists of the key partner organizations that proposed the project and provided critical input at all stages in regular project team meetings as well as stakeholder workshop events. The project team evolved over time as the project shifted into different phases.

- Ellie Baker, The Nature Conservancy
- Steve Couture, New Hampshire Department of Environmental Services Coastal Program
- Rebecca Ellin, North Carolina National Estuarine Research Reserve
- Dr. Tess Forsell Hubbard, Eastern Research Group
- Kirsten Howard, New Hampshire Department of Environmental Services Coastal Program
- Dr. Lou Nadeau, Eastern Research Group
- Arleen O'Donnell, Eastern Research Group
- Cory Riley, Great Bay National Estuarine Research Reserve
- Rachel Rouillard, Piscataqua Region Estuaries Partnership
- Dr. Pete Wiley, National Oceanic and Atmospheric Administration
- Chris Williams, New Hampshire Department of Environmental Services Coastal Program

Former members

- Dr. Ray Konisky, The Nature Conservancy
- Dr. Phil Trowbridge, Piscataqua Region Estuaries Partnership
- Derek Sowers, Piscataqua Region Estuaries Partnership

Stakeholder Advisory Committee (SAC)

This group of individuals provided critical input at several stages in the project. The membership evolved over time as the project shifted into different phases. Members attended workshops and habitat work group meetings, provided data, engaged in one-on-one meetings with the project team members, and provided science-based input as well as expert knowledge to inform and improve draft products. The project team is extremely grateful for the time and expertise generously given by this group.

- Simone Barley-Greenfield, New Hampshire Department of Environmental Services Coastal Program
- Jeff Barnum, Conservation Law Foundation
- Jeannie Brochi, U.S. Environmental Protection Agency
- Dr. David Burdick, University of New Hampshire Jackson Estuarine Laboratory
- Dr. Phil Colarusso, U.S. Environmental Protection Agency
- Alyson Eberhardt, New Hampshire Sea Grant and University of New Hampshire Cooperative Extension
- Robert Eckert, New Hampshire Fish and Game Department
- Jill Farrell, Piscataqua Region Estuaries Partnership
- Brian Gennaco, Virgin Oyster Company
- Stefanie Giallongo, New Hampshire Department of Environmental Services Shellfish Program
- Curt Grimm, University of New Hampshire Carsey Institute
- Dr. Ray Grizzle, University of New Hampshire Jackson Estuarine Laboratory
- Julia Guimond, New Hampshire Department of Environmental Services Shellfish Program
- Dr. John Halstead, University of New Hampshire Department of Natural Resources and Environment

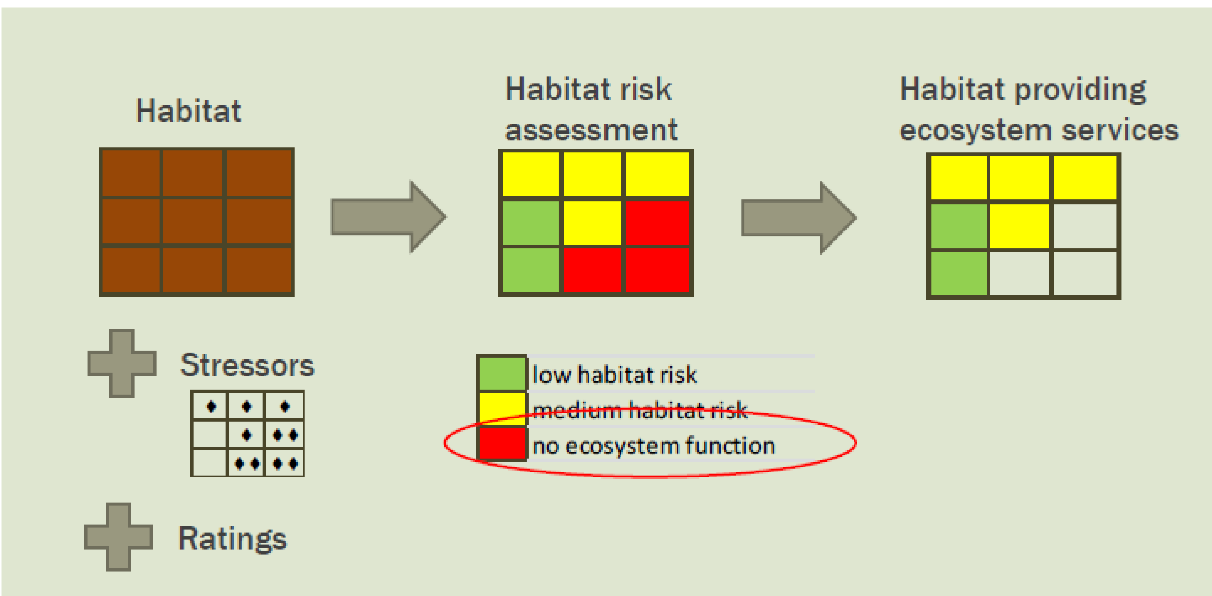
- Dr. Steve Jones, University of New Hampshire Jackson Estuarine Laboratory
- Dr. Rich Langan, University of New Hampshire
- Kevin Lucey, New Hampshire Department of Environmental Services Coastal Program
- Wendy Lull, Seacoast Science Center
- Dr. Kalle Matso, Piscataqua Region Estuaries Partnership
- Nathalie Morison, New Hampshire Department of Environmental Services Coastal Program
- Dr. Ru Morrison, Northeast Regional Association of Coastal Ocean Observing Systems
- Chris Nash, New Hampshire Department of Environmental Services Shellfish Program
- Cheri Patterson, New Hampshire Fish and Game Department
- Kyle Pimental, Strafford Regional Planning Commission
- Robert Pruyne, Rockingham Planning Commission
- Dr. Shannon Rogers, Plymouth State University
- Fay Rubin, University of New Hampshire Earth Systems Research Center
- Tracy Shattuck, Pease Development Authority Division of Ports and Harbors
- Dr. Fred Short, UNH Jackson Lab
- Bruce Smith, New Hampshire Fish and Game Department
- Dr. Paul Stacey, Great Bay National Estuarine Research Reserve
- Rachel Stevens, Great Bay National Estuarine Research Reserve
- Dori Wiggin, New Hampshire Department of Environmental Services Wetlands Bureau
- Matt Wood, New Hampshire Department of Environmental Services

Appendix B
Habitat Risk Assessment Methodology & Process

The GBESA future management scenario design approach was based on the Belize Integrated Coastal Zone Management Plan process which used the InVEST Habitat Risk Assessment (HRA) model[1] to identify important habitats at risk of different stressors and adjust those stressors to understand potential habitat change in future scenarios.[2] The HRA model, developed and managed by the Natural Capital Project, is free, open source, and available for download online as part of the InVEST model set.[3]

Figure 1.B. shows a simple visualization of how the HRA model works by pixelating the habitat input and assigning relative risk scores to each habitat cell based on the cumulative impact of the stressors that overlap with that cell. A key assumption made by the Project Team, based on the Belize project approach, is that habitat pixels that result in a risk score of 'high' are too stressed to function properly and therefore are not providing ecosystem services. This assumption establishes a mechanism to design future scenarios with different stressor distributions and intensities that result in different risk scores for habitat pixels and, ultimately, different areas of habitat functioning to provide ecosystem services.

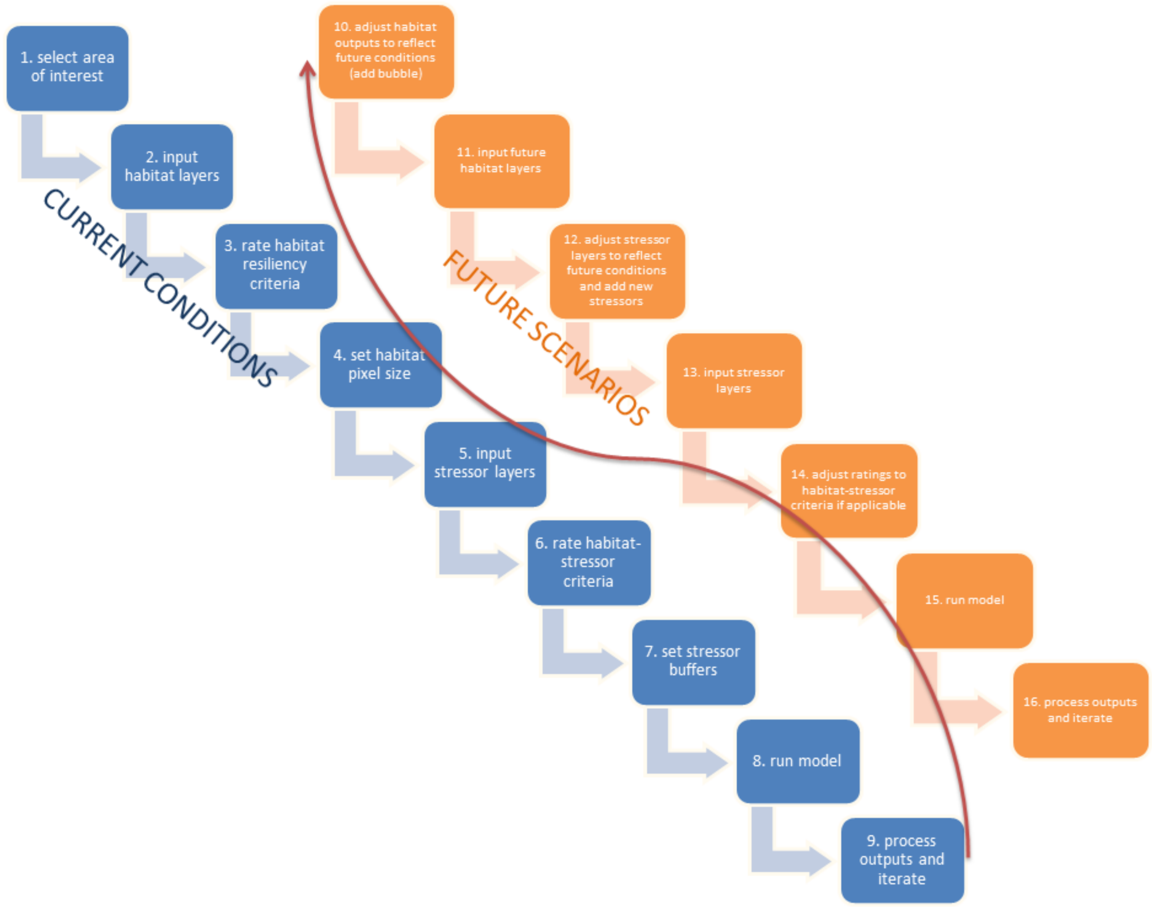
Figure 1.B How the Habitat Risk Assessment Model Works



Though it is important to note that the process was not linear, the generalized steps of the current conditions and future scenario design process for the Great Bay estuary are shown in figure 2.B and key elements of the process are described below.

[1] The Natural Capital Project. Habitat Risk Assessment User Guide. http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/habitat_risk_assessment.html
[2] Rosenthal, Amy, Gregory Verutes, Katie Arkema, Chantalle Clarke, Maritza Canto, Samir Rosado and Spencer Wood. 2015. InVEST Scenarios Case Study: Coastal Belize. The Natural Capital Project.
[3] InVEST: Integrated Valuation of Ecosystem Services and Tradeoffs. http://www.naturalcapitalproject.org/invest/#what-is-invest

Figure 2.B. Habitat Risk Assessment Current Conditions and Future Scenario Modeling Steps



Stakeholder engagement

Stakeholder engagement was critical for the current conditions analysis and scenario design process. Stakeholders were engaged in several ways throughout the process, including one-on-one meetings to collect existing datasets and literature, obtain expert opinion, check results, and suggest alterations. Stakeholders were also engaged in group discussions about the scenarios in three SAC workshops as well as in three Habitat Working Group meetings (one each for eelgrass, saltmarsh, and oyster beds). For a list of the stakeholders engaged in the GBESA project, see Appendix A.

Area of interest and habitat pixel area

The first input required to run the HRA model is a spatial area of interest. The Project Team selected the Great Bay estuary, including all existing and future potential salt marsh areas, up the tidal rivers to the head of tide, and downstream to the edge of the water quality sampling area for the Portsmouth Harbor as defined by the New Hampshire Department of Environmental Services. This area encompasses all of the habitat to be modeled by the HRA—saltmarsh, eelgrass, and oyster bed areas within the Great Bay estuary.

Identification of key habitats, stressors, and corresponding spatial data

In the fall of 2013, the Project Team put together a list of the key habitats and the ecosystem services provided by those habitats that are most important to the people that benefit from the Great Bay estuary. At the first SAC workshop, held in December 2013, stakeholders provided input for the selection of habitats, ecosystem services of interest, and stressors that informed the conceptual model depicted in Section 1.2.

At the same workshop, the SAC members brainstormed available spatial data that could be used as inputs representing habitats and stressors for the current conditions HRA. Following the workshop, the Project Team followed up with several SAC members and others to obtain datasets. In the case of docks, hardened shorelines, sediment impact, and shellfish harvest, these stressors were deemed important to the analysis, however spatial datasets did not exist, so the Project Team digitized datasets using 2013 orthophotography for the region. Each stressor layer was given a buffer distance, based on findings in the literature and SAC knowledge, to account for the impact it has on habitats beyond the spatial layer's depiction of the boundary of the stressor. The habitat and stressor input datasets with buffer distances for the current conditions HRA are listed in Table 1.B and the stressors relevant to each habitat are marked with an 'X'. Figures 3.B, 4.B, and 5.B show the spatial distribution of the current stressors on the current habitat maps for eelgrass, salt marsh, and oyster beds respectively. Much of the spatial stressor and habitat data can be downloaded at NH GRANIT http://granit.sr.unh.edu/.[4]

[4] Dataset inputs are available upon request to Kirsten Howard at the NHDES Coastal Program; 603-559-0020 or kirsten.howard@des.nh.gov.

Table 1.B: Habitat and stressor dataset inputs to the current conditions HRA

Stressor/Habitat	**Stressor data Source**	**Buffer distance** (meters)	**Eelgrass** Sources: combined extent of two 2013 datasets available on GRANIT	**Saltmarsh** Source: Saltmarsh extracted from National Wetlands Inventory representing 2012	**Oysters** Source: NHDES managed dataset based on Great Bay Restoration Compendium, combined with more current oyster restoration data from TNC, representing 2013
aquaculture (shellfish)	NHDES	0	X		
depth (bathymetry)	NHDES	0	X		
ditches	UNH Great Bay Restoration Compendium	7		X	
ditch plugs	UNH Great Bay Restoration Compendium	20		X	
federal channels/dredging	Army Corps of Engineers	35	X	X	
hardened shorelines	NHDES (created for GBESA)	10		X	
moorings	NHDES	20	X		X
pens (finfish aquaculture)	NHDES	20	X		X
phragmites	NHDES	20		X	
private docks (small)	NHDES (created for GBESA)	0	X	X	
railroads	NHDOT	10		X	
recreational boating density	Northeast Recreational Boating Survey for 2012	0	X		X
roads	NHDOT	10		X	
sediment (deposition)	NHDES (created for GBESA)	0			X
shared docks (large)	NHDES (created for GBESA)	0	X	X	
shellfish harvest	NHDES (created for GBESA)	0	X		X
tidal restrictions	Great Bay Restoration Compendium and NHDES	0		X	
water light attenuation	NHDES	0	X		

Table 2.B Water light attenuation stressor for current conditions eelgrass habitat risk assessment

Update using Data from 2008-2012						
	Kd (m^{-1})		Depth (m MTL)			Eelgrass Light Stress
Assessment Zone	N	Median	Z_{min}	Z_{max}	Z_{min}-Z_{max}	
SQUAMSCOTT RIVER NORTH	42	3.02	-1.00	-0.5	-0.5	High
LAMPREY RIVER NORTH	35	1.67	-1.00	-0.9	-0.1	High
OYSTER RIVER	28	1.44	-1.00	-1.1	0.1	Medium
BELLAMY RIVER	2	1.21	-1.00	-1.3	0.3	Insuff. Data
COCHECO RIVER	1	1.42	-1.00	-1.1	0.1	Insuff. Data
SALMON FALLS RIVER	0					Insuff. Data
GREAT BAY	49	1.12	-1.00	-1.4	0.4	Medium
LITTLE BAY	51	0.97	-1.00	-1.6	0.6	Medium
UPPER PISCATAQUA RIVER	36	1.51	-1.00	-1.0	0.0	High
LOWER PISCATAQUA RIVER - NORTH	2	0.82	-1.00	-1.9	0.9	Insuff. Data
LOWER PISCATAQUA RIVER - SOUTH	1	0.43	-1.00	-3.5	2.5	Insuff. Data
PORTSMOUTH HARBOR	34	0.63	-1.00	-2.4	1.4	Low
LITTLE HARBOR/BACK CHANNEL	1	1.36	-1.00	-1.1	0.1	Insuff. Data
SQUAMSCOTT RIVER SOUTH	7	3.59				Insuff. Data

In order to create the water light attenuation stressor that serves as a partial proxy measure of water pollution stress on eelgrass, table 9 from the 2009 NHDES report Numeric Nutrient Criteria for the Great Bay Estuary[5] with more recent data for light attenuation (measured with the light attenuation coefficient Kd) from 2008-2012. This table uses a method from Koch (2001)[6] to estimate the minimum and maximum depths for eelgrass survival, assuming that 22% of incident light is required for survival. This approach does not consider any other eelgrass stressors besides light limitation, such as macroalgae, epiphytes, toxicity, and physical disturbance.

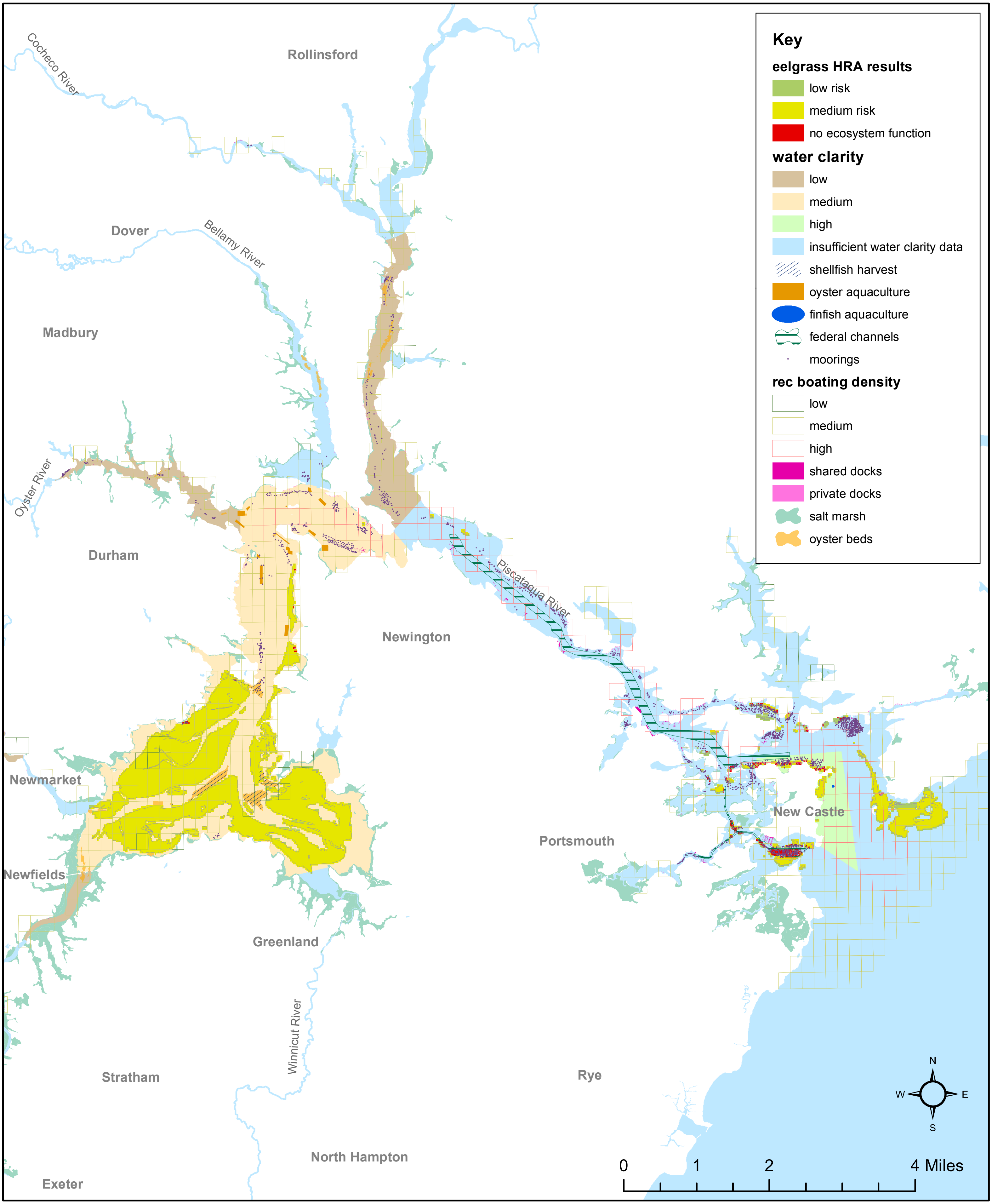
Table 2.B shows the updated numbers from 2008-2012. If there were less than 15 measurements of light attenuation in an assessment zone, the zone was considered to have insufficient information to make an updated assessment of light limitation. A spatial layer was developed that highlighted the eelgrass assessment zones based on their 'Eelgrass light stress' rating.

The minimum depth of eelgrass beds (Zmin) can be predicted from the tide height in the estuary because eelgrass cannot survive above the mean low water line. The tidal range in the estuary is approximately 2 meters. Therefore, ignoring effects of wave action, Zmin will be 1 meter below mean tidal level throughout the estuary. The maximum depth of eelgrass beds (Zmax) in different areas can be predicted from measurements of the light attenuation coefficient and the minimum transmission of surface irradiance needed by eelgrass for survival. The difference between Zmin and Zmax can be used to predict the presence or absence of eelgrass. Koch and Beer (1996) determined that Zmax should be at least 1 meter below (less than) Zmin for eelgrass survival.

[5] Trowbridge, P. (2009). Numeric Nutrient Criteria for the Great Bay Estuary. New Hampshire Department of Environmental Services.
[6] Koch, E.W. 2001. Beyond light: Physical, geological, and geochemical parameters as possible submersed aquatic vegetation requirements. Estuaries 24: 1-17.

Map 3.B: Current Eelgrass: Stressors and Habitat Risk

Current Eelgrass: Stressors and Habitat Risk



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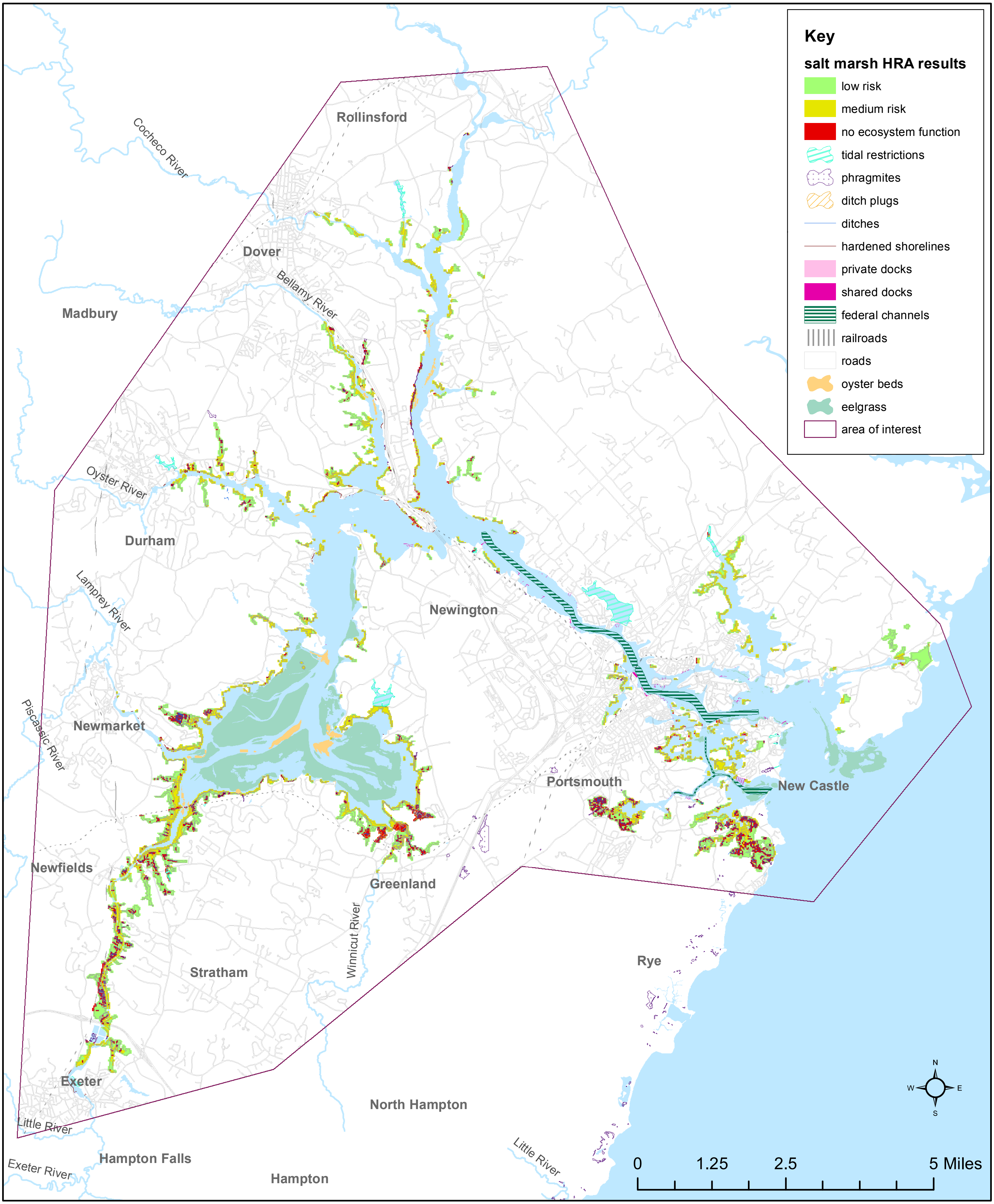
Map 4.B: Current Salt Marsh: Stressors and Habitat Risk

Current Salt Marsh: Stressors and Habitat Risk



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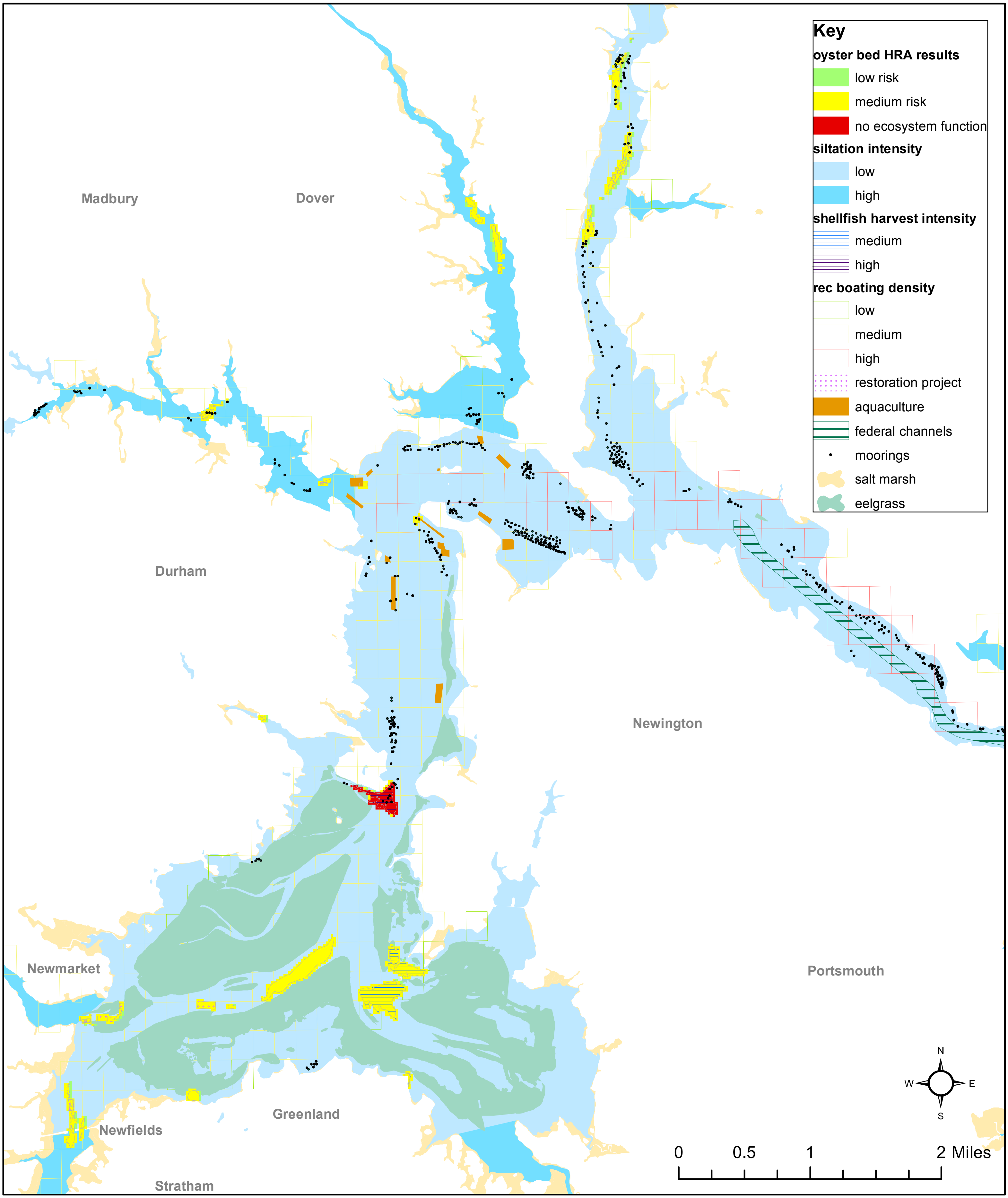
Map 5.B: Current Oyster Beds: Stressors and Habitat Risk

Current Oyster Beds: Stressors and Habitat Risk



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Risk ratings based on scientific literature and expert opinion

The HRA model requires assignment of ratings for several factors associated with the habitats and stressors to determine the impact a given stressor is having on a given habitat in a given location. The ratings are based on existing scientific literature, local data, and expert knowledge. This ranking process and its justification are laid out clearly in the HRA Model User Guide.[7]

After selecting the key habitats and stressors and their associated datasets, the Project Team conducted a literature review to ascertain two categories:

a) The inherent characteristics of the key habitats as they relate to the habitat's inherent resiliency to stress.
b) The impacts of each stressor on each habitat as it relates to;
    a. Exposure (i.e., the characteristics of the exposure between a habitat and a stressor)
    b. Consequence of exposure (i.e., assuming a habitat is exposed to a stressor, the results of that exposure on the habitat)

The literature that informed the HRA ratings is listed in Table 3.B.

Table 3.B: Literature referenced for ratings in the Great Bay Habitat Risk Assessment

Habitat	Source
Eelgrass	Johnston, R., Munns, W., Tyler, P., Marajh, W., Finkelstein, K., Munney, K., Short, F.T., Melville, A., and S. Hahn. (2002). Weighing the Evidence of Ecological Risk from Chemical Contamination in the Estuarine Environment Adjacent to the Portsmouth Naval Shipyard, Kittery, Maine, USA. Environmental Toxicology and Chemistry, Vol. 21, No. 1, pp. 182-194.
	Short, F.T. (2014). Nitrogen as an Eelgrass Stressor in Puget Sound. Aquatic Resources Division, Washington State Department of Natural Resources, Olympia, WA. 37p.
	Short, F.T., Neckles, H. (1999). Review: The effects of global climate change on seagrasses. Aquatic Botany 63 pp.169-196.
	Short, F.T., Burdick, D.M., Moore, G.E. (2009). Impacts of Marine Docks on Eelgrass in New England: A Spreadsheet-Based Model for Managers and Planners. Jackson Estuarine Laboratory, University of New Hampshire.
	Nightingale, B., Simenstad, C.A. (2001). White Paper: Overwater Structures: Marine Issues. Prepared for Washington State Transportation Commission, Department of Transportation in cooperation with U.S. Department of Transportation Federal Highway Administration. Washington State Transportation Center, University of Washington.
	West, R.J. Impacts of Recreational Boating Activities on the Seagrass Posidonia in SE Australia. School of Biological Sciences, University of Wollongong. Wetlands(Australia) 26(2).
	Di Carlo G., McKenzie L.J. (2011). Seagrass training manual for resource managers. Conservation International, USA.
	Simenbad, C. 2014. Patterns of Seacoast Community Response to Local Shoreline Development. Estuaries and Coasts. Volume 37, Issue 6, pp 1549-1561.
	Dunton, K. (2014). Effects of Shoreline Alteration and Other Stressors on Submerged Aquatic Vegetation in Subestuaries of Chesapeake Bay and the Mid-Atlantic Coastal Bays. Estuaries and Coasts. Volume 37, Issue 6, pp 1516-1531.

[7] The Natural Capital Project. Habitat Risk Assessment User Guide. http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/habitat_risk_assessment.html

	Neckles, H.A., Short, F.T., Barker, S., Kopp, B. (2005.) Disturbance of eelgrass Zostera marina by commercial mussel Mytilus edulis harvesting in Maine: dragging impacts and habitat recovery. Marine Ecology Progress Series. Vol. 285: 57-73.
	Trowbridge, P. (2009). Numeric Nutrient Criteria for the Great Bay Estuary. New Hampshire Department of Environmental Services.
	Phillips, R.C., Milchakova, N.A. (2003). Seagrass Ecosystems. National Academy of Science of Ukraine.
	Wood, M. A. and Trowbridge, P. (2014). "Nitrogen, Phosphorus, and Suspended Solids Concentrations in Tributaries to the Great Bay Estuary Watershed in 2013" PREP Publications. Paper 252.
	Plummer, M., Harvey, C., Anderson, L., Guerry, A., Ruckelshaus, M. (2013). The Role of Eelgrass in Marine Community Interactions and Ecosystem Services: Results from Ecosystem-Scale Food Web Models. Ecosystems. 16: 237-251.
	Schmidt, A., Coll, M., Romanuk, T., Lotze, H. (2011). Ecosystem structure and services in eelgrass Zostera marina and rockweed Ascophyllum nodosum habitats. Marine Ecology Progress Series. Vol. 437: 51-68.
	Macreadie, P., Baird, M., Trevathan-Tacket, S., Larkum, A., Ralph, P.J. (2014). Quantifying and modelling the carbon sequestration capacity of seagrass meadows - a critial asset. Marine Pollution Bulletin. 83. pp. 430-439.
	Baden, S., Gullstrom, M., Lunden, B., Phil, L., Rosenberg, R. (2003). Vanishing Seagrass (Zostera marina, L.) in Swedish Coastal Waters. Ambio Vol. 32 No. 5.
Salt marsh	Deegan, L., Johnson, D.S., Warren, R., Peterson, B., Fleeger, J., Fagherazzi, S., Wollheim, W. (2012). Coastal eutrophication as a driver of salt marsh loss. Nature. Vol. 490.
	Alexander, C., Robinson, M. (2006). Quantifying the ecological significance of marsh shading: the impact of private recreational docks in coastal Georgia. Coastal Resources Division, Georgia Department of Natural Resources.
	Hartig, E., Gornitz, V., Kolker, A., Mushacke, F., Fallon, D. (2002). Anthropogenic and climate-change impacts on salt marshes of Jamaica Bay, New York City. Wetlands. Vol. 22, No. 1, pp. 71-89.
	Kirwan, M.L., Guntenspergen, G.R. (2012). Feedbacks between inundation, root production, and shoot growth in a rapidly submerging brackish marsh. Journal of Ecology (100) pp.764-770.
	Konisky, R., Burdick, D., Dionne, M., Neckles, H. (2006). A Regional Assessment of Salt Marsh Restoration and Monitoring in the Gulf of Maine. Restoration Ecology. Vol. 14, No. 4, pp. 516-525.
	Reilly, P., Bottitta, G., Burdick, D., Vincent, R., Wilson, G. (2006). Little River II Pilot Projects: NOAA Community-Based Restoration Partnership Projects. Submitted to New Hampshire Coastal Program, Department of Environmental Services.
	Moore, G., Peter, C., Burdick, D., Keirstead, D. (2009). Status of the Eastern Grasswort, Lilaeopsis chinensis (Apiaceae), in the Great Bay Estuary, New Hampshire, USA. Rhodora: Journal of the New England Botanical Club. Vol. 111, No. 946, pp. 171-188.
	Normandeau Associates, Inc. (2007). Inventory and Analysis of Tidal Wetlands. Prepared for New Hampshire Coastal Program, Office of State Planning and Energy Programs.
	Burdick, D. and Short, F.T. (2010). New Hampshire Port Authority Salt Marsh Mitigation Monitoring Final Report 1993-2010. Jackson Estuarine Laboratory, University of New Hampshire. Prepared for New Hampshire Port Authority and the New Hampshire Department of Transportation.
	Turner, E., Howes, B., Teal, J., Milan, C., Swenson, E., Geohringer-Toner, D. (2009). Salt marshes and eutrophication: an unsustainable outcome. Linol. Oceanogr., 54(5), pp. 1634-1642.

	Vincent, R., Burdick, D., Dionne, M. (2013). Ditching and Ditch-Plugging in New England Salt Marshes: Effects on Plant Communities and Self-Maintenance. Estuaries and Coasts.
	Bozek, C., Burdick, D. (2005). Impacts of seawalls on saltmarsh plant communities in the Great Bay Estuary, New Hampshire USA. Wetlands Ecology and Management 13: 553-568.
Oyster beds	Smith, B. (2013). Review of Oyster Data 2013. New Hampshire Fish & Game Department.
	Grizzle, R. (2011). Development of guidelines for using bioextraction technologies to manage nutrients in New Hampshire's estuarine waters. Jackson Estuarine Laboratory, University of New Hampshire. Submitted to New Hampshire Sea Grant.
	Konisky, R., Grizzle, R., Ward, K., Eckert, R., McKeton, K. (2014). Scaling Up: A Fifth Year of Restoring Oyster Reefs in Great Bay Estuary, NH: 2013 Annual Program Report. The Nature Conservancy and the University of New Hampshire.
	Bricker, S., Ferreira, J., Zhu, C., Galimany, R., Wikfors, G., Saurel, C., Miller, R., Wands, J., Trowbridge, P., Grizzle, R., Wellman, K., Rheault, R., Steinberg, J., Jacob, A., Davenport, E., Ayvazian, S., Chintala, M., Tedesco, M. (in review at time of GBESA, 2015). An Ecosystem Services Assesment Using Bioextraction Technologies for Removal of Nitrogen and Other Substances in Long Island Sound and the Great Bay/Piscataqua Region. NCCOS Coastal Ocean Program Decision Analsysis Series No. 194. NOAA.

Following the literature review, the Project Team assigned preliminary ratings to the habitats as well as the habitat-stressor relationship factors. These factors are rated on a scale of zero to three. Zero means the factor is not applicable, one equals low impact, two equals medium impact, and three equals high impact. However, a more specific rubric is assigned to each individual factor, as shown in Figure B.1.

Subsequently, the Project Team held six Habitat Working Group meetings with members of the SAC to review the preliminary scores and adjust them as deemed necessary. The Habitat Working Groups were divided by habitat—therefore two meetings were held with an Eelgrass Working Group consisting of local eelgrass experts, two meetings were held with a Salt Marsh Working Group consisting of local salt marsh experts, and two meetings were held with an Oyster Working Group consisting of local oyster habitat experts. For each habitat type, the first Habitat Working Group meeting consisted of reviewing the stressor and habitat maps, explaining the preliminary ratings proposed for the habitat and habitat-stressor relationships, and discussing necessary adjustments to the proposed ratings for the habitat in question. The second Habitat Working Group meeting consisted of showing the first round of modeled Habitat Risk Assessment map results in which habitat pixels were ranked “high risk,” “medium risk,” and “low risk.” The groups looked back at the rating data inputs that determined each of the results and proposed adjustments to the ratings where results were inconsistent with local knowledge. The habitat risk assessment factors and definitions are described below along with the rating rubrics used to assign ratings.[8]

[8] The Natural Capital Project. Habitat Risk Assessment User Guide. http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/habitat_risk_assessment.html

HABITAT RESILIENCE (ranking, data quality, weight)

Recruitment rate
Frequent recruitment increases recovery potential by increasing the chance that incoming propagules can re-establish a population in a disturbed area.

	High (3)	Medium (2)	Low (1)	No score (0)
Natural recruitment rate	Every 2+ yrs	Every 1-2 yrs	Annual or more often	N/A

Natural mortality rate
Habitats with high natural mortality rates are generally more productive and more capable of recovery.

	High (3)	Medium (2)	Low (1)	No score (0)
Natural mortality rate	Low mortality (e.g. 0-20%)	Moderate mortality (e.g. 20-50%)	High mortality (e.g.80% or higher)	N/A

Connectivity rate
Larval/seed dispersal and close spacing of habitat patches increases the recovery potential of a habitat by increasing the chance that incoming propagules can re-establish a population in a disturbed area.

	High (3)	Medium (2)	Low (1)	No score (0)
Connectivity	Low dispersal (less than 10km)	Medium dispersal (10-100km)	High dispersal (>100km)	N/A

Recovery time
Biotic habitats that reach maturity earlier are likely to be able to recover more quickly from disturbance than those that take longer to reach maturity. Here we refer to maturity of the habitat as a whole (i.e., a mature kelp forest) rather than reproductive maturity of individuals. For abiotic habitats, shorter recovery times for habitats such as mudflats decrease the consequences of exposure to human activities. In contrast, habitats made of bedrock will only recover on geological time scales, greatly increasing the consequences of exposure.

	High (3)	Medium (2)	Low (1)	No score (0)
Age at maturity/ recovery time	More than 10 yrs	1-10yrs	Less than 1 yr	N/A

EXPOSURE (ranking, data quality, weight)

Change in area

Change in area is measured as the percent change in areal extent of a habitat when exposed to a given stressor and thus reflects the sensitivity of the habitat to the stressor. Habitats that lose a high percentage of their areal extent when exposed to a given stressor are highly sensitive, while those habitats that lose little area are less sensitive and more resistant.

	High (3)	Medium (2)	Low (1)	No score (0)
Change in area	High loss in area (50-100%)	Medium loss in area (20-50%)	Low loss in area (0-20%)	N/A

Change in structure

For biotic habitats, the change in structure is the percentage change in structural density of the habitat when exposed to a given stressor. For example, change in structure would be the change in shoot density for seagrass systems, change in polyp density for corals, or change in stipe density for kelp systems. Habitats that lose a high percentage of their structure when exposed to a given stressor are highly sensitive, while habitats that lose little structure are less sensitive and more resistant. For abiotic habitats, the change in structure is the amount of structural damage sustained by the habitat. Sensitive abiotic habitats will sustain complete or partial damage, while those that sustain little to no damage are more resistant. For example, gravel or muddy bottoms will sustain partial or complete damage from bottom trawling while hard bedrock bottoms will sustain little to no damage.

	High (3)	Medium (2)	Low (1)	No score (0)
Change in structure	High loss in structure (for biotic habitats, 50-100% loss in density, for abiotic habitats, total structural damage)	Medium loss in structure (for biotic habitats, 20-50% loss in density, for abiotic habitats, partial structural damage)	Low loss in structure (for biotic habitats, 0-20% loss in density, for abiotic habitats, little to no structural damage)	N/A

Frequency of similar natural disturbance

If a habitat is naturally frequently perturbed in a way similar to the anthropogenic stressor, it may be more resistant to additional anthropogenic stress. For example, habitats in areas that experience periodical delivery of nutrient subsidies (i.e. from upwelling or allocthonous inputs such as delivery of intertidal plant material to subtidal communities) are adapted to variable nutrient conditions and may be more resistant to nutrient loading from netpen salmon aquaculture. This criterion is scored separately for each habitat-stressor combination, such that being adapted to variable nutrient conditions increases resistance to nutrient loading from salmon aquaculture but not destructive fishing. However, high storm frequency may increase resistance to destructive fishing, because both stressors impact habitats in similar ways.

	High (3)	Medium (2)	Low (1)	No score (0)
Frequency of natural disturbance	Annually or less	Several times per	Daily to	N/A

	High (3)	Medium (2)	Low (1)	No score (0)
	often	year	weekly	

CONSEQUENCE (ranking, data quality, weight)

Temporal overlap

Temporal overlap is the duration of time that the habitat and the stressor experience spatial overlap. Some stressors, such as permanent overwater structures, are present year-round; others are seasonal, such as certain fishing practices. Similarly, some habitats (e.g. mangroves) are present year round, while others are more ephemeral (e.g. some seagrasses).

	High (3)	Medium (2)	Low (1)	No score (0)
Temporal overlap	Habitat and stressor co-occur for 8-12 months of the year	Habitat and stressor co-occur for 4-8 months of the year	Habitat and stressor co-occur for 0-4 months of the year	N/A

Management effectiveness

Management can limit the negative impacts of human activities on habitats. For example, policies that require salmon aquaculturists to let their farms lie fallow may reduce the amount of waste released and allow nearby seagrasses to recover. Similarly, regulations that require a minimum height for overwater structures reduce the shading impacts of overwater structures on submerged aquatic vegetation. Thus, effective management strategies will reduce the exposure of habitats to stressors. The effectiveness of management of each stressor is scored relative to other stressors in the region. So if there is a stressor that is very well managed such that it imparts much less stress on the system than other stressors, classify management effectiveness as “very effective.” In general, however, the management of most stressors is likely to be “not effective.” After all, you are including them as stressors because they are having some impact on habitats. You can then use this criterion to explore changes in management between scenarios, such as the effect of changing coastal development from high impact (which might receive a score of “not effective”) to low impact (which might receive a score of “somewhat effective).”

	High (3)	Medium (2)	Low (1)	No score (0)
Management effectiveness	Not effective, poorly managed	Somewhat effective	Very effective	N/A

Intensity

The exposure of a habitat to a stressor depends not only on whether the habitat and stressor overlap in space and time, but also on the intensity of the stressor. The intensity criterion is stressor-specific. For example, the intensity of nutrient-loading stress associated with netpen salmon aquaculture is related to the number of salmon in the farm and how much waste is released into the surrounding environment. Alternatively, the intensity of destructive shellfish harvesting is related to the number of harvesters and the harvest practices. You can use this intensity criteria to explore how changes in the intensity of one stressor might affect risk to habitats. For example, one could change the intensity score to represent changes in the stocking density of a salmon farm in a future scenario. One can also use this ranking to incorporate relative differences in the intensity of different stressors within the study region. For example, different types of marine transportation may have different levels of intensity. For example, cruise ships may be a more intense stressor than water taxis because they release more pollutants than the taxis do.

	High (3)	Medium (2)	Low (1)	No score (0)
Intensity	High intensity	Medium intensity	Low intensity	N/A

The final ratings for the current conditions HRA model are listed in Tables , 4.B, 5.B, and 6.B.

Table 4.B: Current conditions and future scenario ratings for eelgrass

HRA Factors	Current Conditions			2025 Scenario: Lose Habitats and Benefits			2025 Scenario: Gain and Sustain Habitats and Benefits		
HABITAT RESILIENCE	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
recruitment rate	1	1	1	1	1	1	1	1	1
natural mortality rate	1	1	1	1	1	1	1	1	1
connectivity rate	2	2	1	2	2	1	2	2	1
recovery time	2	1	1	2	1	1	2	1	1
HABITAT STRESSOR OVERLAP									
AQUACULTURE SHELLFISH	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	3	1	3	3	1	3	3	1
change in area rating	3	2	1	3	2	1	3	2	1
change in structure rating	3	2	1	3	2	1	3	2	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	2	3	1	3	3	1	1	3	1
intensity rating	3	1	1	3	1	1	2	1	1
DEPTH	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	1	1	1	1	1	1	1	1	1
change in area rating	1	1	1	1	1	1	1	1	1
change in structure rating	2	1	1	2	1	1	2	1	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	1	3	1	1	3	1	1	3	1
intensity rating	2	2	1	2	2	1	2	2	1
FEDERAL CHANNELS/DREDGING	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	3	1	3	3	1	3	3	1
change in area rating	3	3	1	3	3	1	3	3	1
change in structure rating	3	3	1	3	3	1	3	3	1

temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	3	3	1	3	3	1	2	3	1
intensity rating	3	1	1	3	1	1	3	1	1
MOORINGS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	2	1	2	2	1	2	2	1
change in area rating	3	1	1	2	1	1	2	1	1
change in structure rating	3	1	1	1	1	1	1	1	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	3	1	1	3	1	1	2	1	1
intensity rating	2	3	1	2	3	1	1	3	1
AQUACULTURE FINFISH	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	3	1	3	3	1	3	3	1
change in area rating	3	2	1	3	2	1	3	2	1
change in structure rating	3	2	1	3	2	1	3	2	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	2	3	1	2	3	1	2	3	1
intensity rating	3	1	1	3	1	1	3	1	1
PRIVATE DOCKS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	2	1	3	2	1	3	2	1
change in area rating	3	1	1	3	1	1	3	1	1
change in structure rating	3	1	1	3	1	1	3	1	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	2	3	1	3	3	1	2	3	1
intensity rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1
RECREATIONAL BOATING DENSITY	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	2	3	1	2	3	1	2	3	1

change in area rating	1	1	1	1	1	1	1	1	1
change in structure rating	1	1	1	1	1	1	1	1	1
temporal overlap rating	2	3	1	2	3	1	2	3	1
management effectiveness	2	3	1	3	3	1	1	3	1
intensity rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1
SHARED DOCKS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	2	1	3	2	1	3	2	1
change in area rating	3	1	1	3	1	1	3	1	1
change in structure rating	3	1	1	3	1	1	3	1	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	3	3	1	3	3	1	2	3	1
intensity rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1
SHELLFISH HARVEST (RECREATIONAL)	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	2	3	1	2	3	1	2	3	1
change in area rating	1	2	1	1	2	1	1	2	1
change in structure rating	1	2	1	1	2	1	1	2	1
temporal overlap rating	2	1	1	2	1	1	2	1	1
management effectiveness	3	3	1	3	3	1	2	3	1
intensity rating	2	3	1	2	3	1	1	3	1
WATER LIGHT ATTENUATION	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	2	1	1	2	1	1	2	1	1
change in area rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1
change in structure rating	SHAPE	2	1	SHAPE	2	1	SHAPE	2	1
temporal overlap rating	3	2	1	3	2	1	3	2	1
management effectiveness	3	1	1	3	1	1	1	1	1
intensity rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1

Table 5.B: Current conditions and future scenario ratings for saltmarsh

HRA Factors	Current Conditions			2025 Scenario: Lose Habitats and Benefits			2025 Scenario: Gain and Sustain Habitats and Benefits		
	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
recruitment rate	3	2	1	3	2	1	3	2	1
natural mortality rate	0	3	1	0	3	1	0	3	1
connectivity rate	1	3	1	1	3	1	1	3	1
recovery time	3	1	1	3	1	1	3	1	1
DITCHES	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	1	1	1	1	1	1	1	1	1
change in area rating	1	1	3	1	1	3	1	1	3
change in structure rating	2	1	3	2	1	3	2	1	3
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	2	2	3	2	2	3	2	2	3
intensity rating	1	1	1	1	1	1	1	1	1
DITCH PLUGS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	2	1	1	2	1	1	2	1	1
change in area rating	2	1	3	2	1	3	2	1	3
change in structure rating	2	1	3	2	1	3	2	1	3
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	2	2	3	2	2	3	2	2	3
intensity rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1
FEDERAL CHANNELS/DREDGING	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	3	1	3	3	1	3	3	1
change in area rating	3	2	1	3	2	1	3	2	1

change in structure rating	2	2	1	2	2	1	2	2	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	3	3	1	3	3	1	2	3	1
intensity rating	2	2	1	2	2	1	2	2	1
HARDENED SHORELINES	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	3	1	3	3	1	3	3	1
change in area rating	3	2	1	3	2	1	3	2	1
change in structure rating	3	2	1	3	2	1	3	2	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	2	3	1	3	3	1	1	3	1
intensity rating	3	1	1	3	1	1	3	1	1
PHRAGMITES	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	3	1	3	3	1	3	3	1
change in area rating	2	2	1	2	2	1	2	2	1
change in structure rating	2	2	1	2	2	1	2	2	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	3	3	1	3	3	1	2	3	1
intensity rating	1	3	1	2	3	1	1	3	1
PRIVATE DOCKS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	3	1	3	3	1	3	3	1
change in area rating	1	2	1	1	2	1	1	2	1
change in structure rating	2	2	1	2	2	1	2	2	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	2	3	1	3	3	1	1	3	1
intensity rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1
RAILROADS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight

frequency of disturbance	3	3	1	3	3	1	3	3	1
change in area rating	1	3	1	1	3	1	1	3	1
change in structure rating	3	3	1	3	3	1	3	3	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	3	3	1	3	3	1	3	3	1
intensity rating	1	3	1	1	3	1	1	3	1
ROADS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	1	1	1	1	1	1	1	1	1
change in area rating	1	3	1	1	3	1	1	3	1
change in structure rating	2	3	1	2	3	1	2	3	1
temporal overlap rating	3	3	1	3	3	1	3	3	1
management effectiveness	2	3	1	2	3	1	2	3	1
intensity rating	3	3	1	3	3	1	3	3	1
SEDIMENT	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	1	1	1	1	1	1	1	1	1
change in area rating	1	3	1	1	3	1	1	3	1
change in structure rating	2	3	1	2	3	1	2	3	1
temporal overlap rating	3	3	1	3	3	1	3	3	1
management effectiveness	2	3	1	2	3	1	2	3	1
intensity rating	1	3	1	1	3	1	1	3	1
SHARED DOCKS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	3	1	3	3	1	3	3	1
change in area rating	1	2	1	1	2	1	1	2	1
change in structure rating	2	2	1	2	2	1	2	2	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	3	3	1	3	3	1	2	3	1
intensity rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1

TIDAL RESTRICTIONS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	1	1	3	1	1	3	1	1
change in area rating	3	1	1	3	1	1	3	1	1
change in structure rating	3	1	1	3	1	1	3	1	1
temporal overlap rating	3	1	1	3	1	1	3	1	1
management effectiveness	3	1	1	3	1	1	2	1	1
intensity rating	3	3	1	3	3	1	1	3	1

Table 6.B: Current conditions and future scenario ratings for oyster beds

HRA Factors	Current Conditions			2025 Scenario: Lose Habitats and Benefits			2025 Scenario: Gain and Sustain Habitats and Benefits		
HABITAT RESILIENCE	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
recruitment rate	3	1	1	3	1	1	3	1	1
natural mortality rate	SHAPE	1	1	2	1	1	2	1	1
connectivity rate	SHAPE	2	1	2	2	1	2	2	1
recovery time	SHAPE	1	1	2	1	1	2	1	1
HABITAT-STRESSOR OVERLAP									
MOORINGS	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	2	3	3	2	3	3	2	3	3
change in area rating	1	3	1	1	3	1	1	3	1
change in structure rating	1	3	1	1	3	1	1	3	1
temporal overlap rating	2	2	1	2	2	1	2	2	1
management effectiveness	2	2	1	2	2	1	2	2	1
intensity rating	1	3	1	2	3	1	1	3	1
AQUACULTURE FINFISH	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	2	2	3	2	2	3	2	2	3
change in area rating	1	2	1	1	2	1	1	2	1

change in structure rating	2	2	1	2	2	1	2	2	1
temporal overlap rating	3	2	1	3	2	1	3	2	1
management effectiveness	2	2	1	2	2	1	2	2	1
intensity rating	2	2	1	2	2	1	2	2	1
RECREATIONAL BOATING DENSITY	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	3	3	3	3	3	3	3	3
change in area rating	1	3	1	1	3	1	1	3	1
change in structure rating	1	3	1	1	3	1	1	3	1
temporal overlap rating	1	1	1	1	1	1	1	1	1
management effectiveness	2	3	1	2	3	1	1	3	1
intensity rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1
SEDIMENT	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	1	1	1	1	1	1	1	1	1
change in area rating	1	3	1	1	3	1	1	3	1
change in structure rating	2	3	1	2	3	1	2	3	1
temporal overlap rating	2	3	1	2	3	1	2	3	1
management effectiveness	2	3	1	3	3	1	1	3	1
intensity rating	SHAPE	2	1	SHAPE	2	1	SHAPE	2	1
SHELLFISH HARVEST (RECREATIONAL)	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight	Rating	Data Qual.	Weight
frequency of disturbance	3	2	3	3	2	3	3	2	3
change in area rating	1	2	1	2	2	1	1	2	1
change in structure rating	3	2	1	3	2	1	3	2	1
temporal overlap rating	3	1	3	3	1	3	3	1	3
management effectiveness	2	1	1	3	1	1	1	1	1
intensity rating	SHAPE	1	1	SHAPE	1	1	SHAPE	1	1

Spatially-Explicit Ratings for Certain Stressors

The HRA model allows for the impacts from stressors on a habitat to be vary in space across the Great Bay estuary. All stressors-habitat rating cells that show a "SHAPE" rating indicate that risk factor varied spatially. For example, the Water Light Attenuation stressor varied in terms of its impact to eelgrass by eelgrass assessment zone across the estuary. Each zone was given a different "change in area" rating, "change in structure" rating, and "intensity" rating based on the sampling data available for that eelgrass assessment zone. For eelgrass assessment zones that did not have sufficient information, a rating of zero was given, rendering the Water Light Attenuation stressor not applicable for that area. For access to the spatially-explicit stressor layer ratings, please contact Kirsten Howard at kirsten.howard@des.nh.gov.

Data Quality Ratings and Associated Research Gaps

The data quality rating varied for different ratings in the Habitat Risk Assessment. A rating of 3 indicated low data quality, indicating the information used to determine the rating was primarily unpublished and based on expert opinion or anecdotal knowledge. The "management effectiveness" rating was often associated with having low data quality because little information is published evaluating the effectiveness of a stressor's management as it relates to its stress impact on a given habitat. Similarly, the "frequency of similar natural disturbance" rating is often associated with having low data quality because limited published information is available comparing a habitat's adaptation to a natural stressor with its built in resilience to a similar unnatural stressor. Habitat-specific risk factors and habitat-stressor relationship factors that were given a low data quality rating (3), and that therefore may benefit from additional research, include:

Eelgrass:

- shellfish aquaculture: frequency of similar natural disturbance, management effectiveness
- depth: management effectiveness
- federal channels/dredging: frequency of similar natural disturbance, change in area rating, change in structure rating, management effectiveness
- moorings: intensity rating
- finfish aquaculture: frequency of similar natural disturbance, management effectiveness
- private docks & shared docks: management effectiveness
- recreational boating density: frequency of similar natural disturbance, temporal overlap rating, management effectiveness
- recreational shellfish harvest: frequency of similar natural disturbance, management effectiveness, intensity rating

Salt marsh:

- natural mortality rate, connectivity rate
- federal channels/dredging: frequency of similar natural disturbance, management effectiveness
- hardened shorelines: frequency of similar natural disturbance, management effectiveness
- phragmites: frequency of similar natural disturbance, management effectiveness, intensity rating

- private docks & shared docks: frequency of similar natural disturbance, management effectiveness
- railroads: frequency of similar natural disturbance, change in area rating, change in structure rating, management effectiveness, intensity rating
- roads: change in area rating, change in structure rating, temporal overlap rating, management effectiveness, intensity rating
- tidal restrictions: intensity rating

Oyster beds:

- moorings: frequency of similar natural disturbance, change in area rating, change in structure rating, intensity rating
- recreational boating density: change in area rating, change in structure rating, temporal overlap rating, management effectiveness

Habitat Pixel Size (Unit of Analysis)

Based on conversations with SAC members, the Project Team chose a habitat pixel area (unit of analysis) of 100 square meters (or approximately 1000 square feet), as an area that represented an appropriate unit of analysis for the three different habitat types; eelgrass, saltmarsh, and oyster beds. The HRA model recommends a minimum unit of analysis of 100 square meters to ensure the model runs properly.

Iteration to adjust stressor layers and ratings

Current conditions HRA results were presented for feedback and iteration at a workshop with the SAC. The SAC provided input on ratings and questioned spatial results that seemed strange. The Project Team also met one-on-one with SAC members to obtain more detailed input about specific ratings and spatial results. More than twelve runs of the HRA were completed on the current conditions data in order to reach the final current conditions results.

Narrative development of future scenarios and spatial layer adjustment and ratings

Once the current conditions results were finalized, the Project Team spent several meetings discussing the options for future scenarios. The group decided that these scenarios are intended to reflect hypothetical stories that demonstrate possible futures at two ends of a spectrum of possibilities. They do not reflect plans or goals for the future. Because of limited time and resources, the Project Team agreed to choose two future scenarios that focused on extreme possibilities for the Great Bay estuary within a reasonable planning timeframe. Initial names for the scenarios were “Business As Usual” and “Enhanced Management with Restoration.” However, as the project progressed, various events related to water quality improvements and restoration suggested that the “Business As Usual” scenario was no longer the path that stakeholders in the Great Bay estuary are on, though it is still a possible outcome if existing plans change. In part for that reason and in part to focus the scenarios on their relationship to ecosystem services, the scenario names were changed to “Lose Habitats and Benefits” and “Gain and Sustain Habitats and Benefits.” See Section 3 for the final future Scenario narrative descriptions. The SAC provided input on scenario narratives, associated spatial data adjustments, and HRA ratings in a workshop and in one-on-one meetings.

The spatial habitat layers and the stressor layers were adjusted to represent each future scenario. Table 7.B summarizes the adjustments that were made to each layer by scenario. Tables 4.B, 5.B, and 6.B show the ratings for each scenario compared to the current conditions scenario.

Table 7.B HRA scenario model inputs: Spatial adjustments made to habitats and stressors for future scenarios

Habitat	2025 Scenario: Lose Habitats & Benefits	2025 Scenario: Gain & Sustain Habitats & Benefits
Eelgrass	Used outputs from current conditions HRA.	Used 1996 extent of eelgrass together with a couple small active restoration locations as model input based on input from stakeholders. Based on PREP's CCMP eelgrass acreage goal.
Saltmarsh	Used Sea Level Affecting Marshes model (SLAMM) outputs for 2025 based on 1 meter of sea-level rise by 2100. Increase in acreage shown for Great Bay estuary compared to current, due to marsh ability to keep up with sea-level rise through 2025. Base marsh map is NWI.	Used Sea Level Affecting Marshes model (SLAMM) outputs for 2025 based on 1 meter of sea-level rise by 2100. Increase in acreage shown for Great Bay estuary compared to current, due to marsh ability to keep up with sea-level rise through 2025. Added restoration at several tidal restrictions, assuming tidal restriction removal. Base marsh map is NWI.
Oyster beds	Used outputs from current conditions HRA.	Used outputs from current conditions HRA and added 100 acres of oyster restoration in the Great Bay channel area based on discussions with The Nature Conservancy.
Stressor		
aquaculture (shellfish)	Based on a historical analysis of oyster aquaculture industry growth as well as two site suitability analyses (NHDES and UNH), 68 acres of permitted oyster aquaculture area were added to the current conditions layer. Sites were limited to areas currently open for shellfish harvest. Sites avoided current eelgrass but did not avoid historical eelgrass areas.	Based on a historical analysis of oyster aquaculture industry growth as well as two site suitability analyses (NHDES and UNH), 101 acres of permitted oyster aquaculture area were added to the current conditions layer. Several sites currently closed for shellfish harvest were assumed to be open due to water quality improvements. Sites avoided the 1996 extent of eelgrass as well as eelgrass restoration planned in this scenario.
depth (bathymetry)	No change to current conditions.	No change to current conditions.
ditches	No change to current conditions.	No change to current conditions.
ditch plugs	No change to current conditions.	No change to current conditions.
federal channels/dredging	Added the Seacoast Reliability Project proposed path to the project. Little Harbor dredging project was added and management effectiveness was rated poor.	Little Harbor dredging project was added and management effectiveness was rated as improved compared to Lose Scenario.
hardened shorelines	Added 10 percent more linear feet of hardened shorelines at locations around the tidal shoreline. Placement of new hardened structures was influenced by existing hardened structures and presence of buildings.	Using the current conditions layer as a baseline, removed all hardened structures on conservation lands and identified in the SLAMM restoration opportunities layer.
moorings	Based on conversations with the Division of Ports and Harbors, conducted a historical analysis of mooring field capacity, assessed existing waitlist for moorings, and added moorings to existing mooring fields that are not currently at maximum capacity. 177 moorings were added.	No change to current conditions, however ratings reflect that all moorings have been changed to "habitat-friendly" moorings, resulting in lower impact to habitats.
pens (finfish aquaculture)	No change to current conditions.	No change to current conditions.
phragmites	Expanded area already colonized by phragmites by 10 percent. Focused on areas identified by stakeholders and areas that have existing tidal restrictions.	Removed 10 percent of existing phragmites, assuming active management and restoration. Removed sites located near tidal restrictions that were removed in this scenario.
private docks (small)	70 docks totaling 61,666 square feet of dock area were added to the current conditions layer to reflect a 10 percent increase in docks in the Great Bay estuary, in line with population projections. Docks were added in random locations, but spaced appropriately from neighboring	No change to current conditions.

	docks.	
railroads	No change to current conditions.	No change to current conditions.
recreational boating density	Assuming an increase in recreational boating activity, the recreational boating layer's spatially-explicit intensity ratings were adjusted. All pixels identified as "low" density were increased to "medium" density. All pixels identified as "medium" density were increased to "high" density. All "high" density pixels remained "high."	Assuming an increase in recreational boating activity, the recreational boating layer's spatially-explicit intensity ratings were adjusted. Outside of Great Bay proper, the layer was adjusted identically to the Lose Scenario. Inside of Great Bay proper, all pixels inside the deep Great Bay channel were changed to "high" density and all pixels overlapping with this scenario's eelgrass input layer were rated "low" density. This scenario adjustment reflects that clear navigation markers and enforcement result in boat traffic routed in the deeper Great Bay channel as opposed to over shallow eelgrass beds where risk of propeller scars and groundings are high.
roads	No change to current conditions.	No change to current conditions.
sediment (deposition)	No change to current conditions layer, however ratings reflect that sediment stress on oyster beds has increased due to improper management and a change in intensity of impacts.	No change to current conditions layer, however ratings reflect that sediment stress on oyster beds has increased due to improper management and a change in intensity of impacts.
shared docks (large)	Added two large, shared docks; one in Dover and one in Newmarket. Siting was based on discussions with stakeholders regarding a plausible number of additional marinas over ten years, but locations are not intended to reflect actual plans for marinas. They have not been evaluated for feasibility.	No change to current conditions.
shellfish harvest	Spatially-explicit harvest intensity rating was increased (higher intensity of harvest per unit of oysters) along with management effectiveness rating (worse management).	Spatially-explicit harvest intensity rating was decreased (lower intensity rating of harvest per unit of oysters) along with management effectiveness rating (better management).
tidal restrictions	No change to current conditions.	Stubbs Pond and several other current tidal restrictions were removed.
water light attenuation	All eelgrass assessment zones currently rated "low eelgrass stress" were changed to "medium eelgrass stress," areas rated "medium eelgrass stress" were changed to "high eelgrass stress," and areas rated "high eelgrass stress" remained "high."	All eelgrass assessment zones currently rated "high eelgrass stress" were changed to "medium eelgrass stress," areas rated "medium eelgrass stress" were changed to "low eelgrass stress," and areas rated "low eelgrass stress" remained "low."

Final current conditions and future scenario HRA results

The final results from the current conditions analysis and future scenario analyses are summarized in Section 3 of this report. Spatial output layers were processed and adjusted slightly based on final input from SAC. The results include data regarding acreage of present by habitat for each scenario as well as maps that lay out the spatial distribution of habitat by scenario. These results were used to estimate a variety of ecosystem services provided by habitats in the future. Section 4 presents the associated ecosystem services results.

Appendix C:
Descriptions and Outcome from Phase 2 Stakeholder Meetings

Throughout the project, stakeholder input played a critical role in the process and results. During Phase 2 of the project, ERG led a stakeholder involvement effort that built upon the Stakeholder Advisory Committee meeting model developed in Phase 1. The Project Team conducted a review of the engaged stakeholders and added additional people to the SAC to fill information and knowledge gaps. For example, aquaculture farmers were invited to meetings in Phase 2. This Appendix describes how stakeholder input was obtained and used to inform the project process throughout Phase 2.

C.1 November 2015 Stakeholder Meeting

The first Phase 2 stakeholder meeting was held at the NHCP office in Portsmouth, NH on November 19, 2015. As stakeholders arrived, each person was asked to vote on which ecosystem services within each habitat were most important to them (see Figure C-1).[1] At the start of the meeting, NHCP presented detailed results from the habitat risk modeling it conducted (described in Section **Error! Reference source not found.** of the report). ERG then presented an overview of economic valuation to provide stakeholders with background on how the ecosystem services would be valued. The stakeholders were then broken into three groups, one for each habitat, and asked to discuss the following questions for the ecosystem services that received the most votes at the start of the meeting:

- What ecosystem function, form, or process leads to the benefit?
- What are the benefits from this service?
- Who benefits from the service?
- What metrics or indicators can be used to measure the improvement in the service under Scenario B?
- What data can we use to estimate the size of the beneficiary group?

[1] ERG listed a set of ecosystem services on a flip chart for each of the three habitats. Stakeholders were provided with five color-coded stickers for each habitat and could use those to vote as they wished; that is, they could place all five stickers on one ecosystem service or divide them up.

- What data can be used to link Great Bay benefits to economic values?

Figure C-1
Vote Results for Ecosystem Services from First Stakeholder Meeting

Each group had a note taker and the meeting wrapped up with a brief report-back from each group to the larger group as a whole. A primary outcome from the meeting was a set of ecosystem services for ERG to focus on in our initial valuation work:

- Recreational fishing
- Recreational oyster harvesting
- Commercial fishing
- Carbon sequestration
- Nitrogen removal

Furthermore, based on discussions during this meeting and subsequent project team meetings, ERG added in existence value to the initial set of estimates. As will be discussed below, the April 2016 stakeholder meeting resulted in de-emphasizing the recreational fishing estimates due to limitations of the estimates and also adding in commercial aquaculture. Our estimates for all ecosystem services we considered appear in the sections that follow.

C.2 April 2016 Stakeholder Meeting

On April 12, 2016, the Project Team hosted a second Phase 2 stakeholder meeting to discuss a draft set of economic value estimates and to think about how those values could be used in outreach and communication products. At the meeting, NHCP reviewed the habitat risk modeling results again and then ERG presented the draft valuation results. This was followed by break-out groups where stakeholders discussed the valuation results for specific ecosystem services and discussed the use of the estimates in communication and outreach. The primary outcomes from the discussion related to the initial economic value estimates were:

- Add in oysters to the carbon sequestration calculations

- Re-assess the nitrogen removal estimates
- Drop the recreational fishing estimates if a better method could not be identified.
- Add in oyster aquaculture
- Commercial fishing and existence value were the “best estimates”

The results reported in Section 4 of the report reflect the outcomes from the April stakeholder meeting.

As noted, the meeting also focused on the best ways to communicate the results of the economic valuation and the associated habitat risk assessment modeling. Overall, the meeting resulted in recommending development of two types of outreach graphics:

- A graphic reflecting the estimates for commercial fishing. The proposed graphic would show the Gulf of Maine and show the estimated value flowing out of Great Bay into the Gulf. ERG was also asked to break out the estimates by state and possibly by Canada.
- A graphic that could be used for several ecosystem services that would show the flow from current conditions to the two future scenarios, highlighting the difference in value between the two scenarios.

ERG developed draft versions of each graphic that were presented in the third stakeholder meeting.

C.3 June 2016 Stakeholder Meeting

The third Phase 2 stakeholder meeting was held on June 10, 2016 with the goal of reviewing the outreach graphics developed by ERG and discussing how those materials could be used by stakeholders to communicate the value of improving the Great Bay estuary. The meeting started with NHCP providing an overview of the habitat risk modeling results. ERG then provided a brief overview of the revised economic value estimates and the remaining project schedule. ERG also presented four draft outreach graphics. The first graphic depicted the value of commercial fishing to the Gulf of Maine; ERG refers to this as the “map graphic”. The other three graphics, referred to as the “flow graphics,” were designed to depict the value of other ecosystem services flowing from the current state to the future states. Since the graphic was designed to be flexible in terms of which ecosystem service it depicted, we varied the background (eelgrass, salt marsh, and oysters were used) and orientation of the information (flowing left to right or top to bottom). The Project Team facilitated three break-out groups where the four graphics were discussed in detail with the goal of identifying changes to graphics and discussing how the graphics would be used in communicating value. This meeting provided the Project Team with substantial input on the graphics which was used to further refine the graphic.

Appendix D:

Guidelines for Using Benefit Transfer in Coastal Restoration Decisions[1]

This Appendix provides the guidelines ERG developed for applying benefit transfers to restoration decisions following events such as natural disasters. The guidelines consist of two separate and related components: (1) a set of "guiding principles" and (2) a process to use in applying benefit transfers to restoration projects. The intended audience for these guidelines are individuals who need to make restoration decisions; economists who assist those making restoration decisions should be familiar with the methods and approaches we are proposing. Although we expect, and highly encourage, the use of individuals with economic expertise to develop the benefit estimates for restoration projects, we also believe that decision-makers need to understand the process used, the advantages, and the limitations of benefit transfers.

Guiding Principles

1. **Use/rely on economic expertise in developing benefit transfers.** Benefit transfers take values estimated using economic valuation techniques at one location (a "study site") and apply those values (with some adjustment) to another location (a "policy site"). This process involves multiple crucial decisions that are best made by someone with economic expertise. For example, decisions need to be made on the appropriateness of the methods used at the study site, how to make adjustments, and valid data to use for the adjustments. These decisions are best done by someone who understand the underpinnings of the economic valuation studies.
2. **Benefit transfers are a good choice for situations where information is needed in a short amount of time.** Developing a study that is specific to the restoration work will take time (and resources). However, the timeline for deciding on restoration work may be short. Benefit transfers can be done in a relatively short amount of time, usually within a few months. Thus, in situation such as coastal restoration where some information is needed quickly, benefit transfers offer the ability to develop benefit estimates that can be used in decision-making.
3. **Benefit transfer values should be only *one* input into any decision-making process.** More specifically, we do not recommend that a value (or values) derived from a benefit transfer process be used as a sole (or driving) factor in making decision. A number of the guiding principles deal with reasons why this is the case. First, all benefit transfers involve error in some form or another; this is discussed in more detail below. Second, in using benefit transfer, only values for some ecosystem services may be available, resulting in an inability to estimate the complete value of a particulate scenario.
4. **If possible, work on the benefit estimates as the projects are being scoped/defined.** It's preferable to have economists working on the benefits estimates during the project scoping, or to at least have them sitting in on the meetings where the work is being defined. This will allow the economist to begin collecting studies and review options early on. It also allows the project team to fully understand the potential applications for benefits estimates as well as the limitations.

[1] This Appendix is adapted from ERG's report, "Hurricane Sandy and the Value of Trade-Offs in Coastal Restoration and Protection," May, 2016.

5. **Post-disaster restoration differs from the context in which most value estimates are made.** Most studies that estimate the benefits of ecosystem services are not focused on post-disaster restoration. That matters for understanding benefit values. In the immediate wake of a disaster, the relative values that people place on different restoration options will mostly likely differ from what they were before a disaster. For example, people may be more willing to pay for protective measures immediately following a disaster. As the disaster fades from memory, people's relative valuation of restoration options will continue to evolve, but may never revert to pre-disaster levels. For example, many people living along the New Jersey shoreline may have an increased value of dunes (as protective measures) relative to the amenity value (ocean views) that dunes degrade compared to before Superstorm Sandy. Thus, in using benefit transfer values, one should keep in mind that relative values can and will change in post-disaster situations and that the values being used in the transfer may not fully reflect the relative values of stakeholders who experienced the disaster.

6. **All benefit transfers involve error.** There are a number of reasons why benefit transfers involve error. First, study sites and policy sites will differ. Even if an economist can make adjustments based on data, some differences between the physical environment and the social characteristics will remain between study and policy sites. These differences generate some level of error. Second, a study that estimates benefits at a study site has some error itself. Specifically, if statistical procedures are used, the resulting estimates will end up with some confidence level around the final value. In summary, taking estimates from one site or sites (the study site(s)) and applying the estimates to another site (policy site) is an imperfect process.

7. **Benefit transfer may be better used to compare across projects rather than to assess the worth of any one project.** If only one restoration project is being considered, using benefit transfers to assess the value of the project is worthwhile. The resulting benefit estimate can provide a sense of whether the project will generate net benefits, subject to the errors involved. ERG expects a better approach would be to use benefit transfers to compare across projects. If benefit transfers are used to generate benefit estimates for multiple projects and those estimates are compared across the projects, the errors will, presumably, be roughly the same for each benefit estimate. This means it may be more accurate to compare relative values derived from benefit transfers rather than a single value itself. A caveat to this, however, would be if studies of differing quality are used in generating the benefit estimates; in this case, the relative values also reflect errors related to the quality of the studies.

8. **Look for specific studies first (or multiple studies to calculate an average) and then fill in any "gaps" using meta-function transfers.** There are a number of ways to perform benefit transfers: (1) find a specific study and use the value from that study, (2) use an average value from multiple studies, (3) apply the statistical function from a previously-estimated study, or (4) use a meta-function estimated from multiple studies. The process we recommend involves first applying (1) and (2) from above and, if no *directly relevant studies* are available, to turn to using a meta-function. One particularly useful set of tools we recommend are the ones developed by John Loomis and colleagues at Colorado State University which provides meta functions to use in benefit transfer exercises.[2]

[2] http://dare.agsci.colostate.edu/outreach/tools/

9. **Calculate benefits over a reasonable time frame.** The benefits will accrue to people over time. Furthermore, costs are incurred up-front on restoration work. The benefits should be calculated for a reasonable time frame and the net present value of the benefits should be compared to costs. In other words, restoration project costs should be viewed as an investment with the return being the ecosystem service values that are generated. To determine the time frame to use, one needs to determine how long the restoration will benefit people. Additionally, all benefit estimates need to be adjusted for inflation.

10. **Do not necessarily aggregate over different benefit estimates.** In cases where benefit estimates for different ecosystem services are drawn from different studies, care should be taken in adding up the values. Additionally, care should also be taken in adding up estimates from a single study if the study used different methods to estimate different values.[3] This is where economic expertise is valuable. An economist can determine when estimated values are comparable and can be added together. Also, there may be some usefulness in providing separate values for different services, allowing stakeholders to better understand where value is being derived in a particular project.

11. **Always assess the possibility of double counting, especially if more than one study is being used.** When using more than one study to estimate benefits, it's necessary to understand if double-counting is occurring. Double-counting may not be clearly seen. For example, a study may not be explicitly estimating the value of a specific service, but the study's estimates may implicitly include the value of the service. Once again, having an economist selecting and reviewing studies is crucially important.

12. **The area being improved by the restoration work may be larger than the area where work is being performed.** The costs and project specifications for restoration work may involve a relatively small area compared to the area that benefits from the work.

Process

1. **Obtain economic expertise.** The first step a decision-maker should take is to find economic expertise in developing the benefit transfer estimates. The expertise can come internally from a decision-maker's organization, or it can be external. In terms of external expertise, we recommend starting with NOAA's Office for Coastal Management and also contacting local universities that have natural resource economics departments. Ultimately, the decision-maker will need someone who can apply benefit transfer methods in a valid manner and then assist in interpreting the resulting estimates.

2. **Develop a narrative that links the restoration (or other action) to benefits.** A key piece of information will be how the proposed restoration work (or other action) will generate benefits. We propose a simple tabular format for this narrative. The table should describe intended work, identify the ecosystem services that will be impacted, describe how the work will improve ecosystem services, and then describe how the ecosystem services benefit people. This narrative will assist the economist in identifying relevant values to use.

[3] This will be highlighted in the case studies we present below.

3. **Identify relevant values to use for valuation.** A key part of any benefit transfer is to identify the relevant values. In the guiding principles above, we recommend looking for specific studies first and then turning to meta-analyses. Three potential sources of studies, and ultimately values, are:

   - The GECOSERV database (http://www.gecoserv.org/) maintained by Harte Institute. Although this database is focused on the ecosystem services in the Gulf of Mexico, it still contains studies from around the U.S. and the world. The advantage of GECOSERV is its focus on coastal and ocean ecosystem services.
   - The Ecosystem Services Partnership Database (http://www.fsd.nl/esp/80763/5/0/50) – This database is maintained by the United Nations Environmental Program (UNEP) The Economics of Ecosystems and Biodiversity (TEEB) project. This database of valuation studies absorbed a number of other databases in the last few years and is recognized as a fairly comprehensive database of valuation studies.
   - The Benefit Transfer and Use Estimating Model Toolkit (http://dare.agsci.colostate.edu/outreach/tools/) developed by John Loomis and colleagues – This set of reports and spreadsheets provides an integrated set of studies that have been rigorously vetted for methods and relevancy. The kit includes spreadsheet models based on meta-analyses that can be used to estimate values in a variety of contexts, as well as average values across studies valuing similar services. The kit also contains references to each study used in the kit so that researchers can explore the studies and find relevant values from the specific studies themselves.

4. **Identify the units needed for estimates.** This step and the prior one are usually done iteratively. We recommend using units such as acres or households. The reason is that those units are usually more easily adapted to available estimates. In many cases, different ecosystem services will require different units. Thus, it may not be possible to select one unit for a valuation project. Rather, units are selected for each service in conjunction with selecting estimated values to use in the transfer.

5. **Estimate the values for the ecosystem services.** Once values have been selected, the value for the improvements can be estimated. This is a step where the economist will need to be heavily involved.

6. **Identify the benefits that cannot be assigned a value and develop a qualitative description of the benefit.** It may not be possible to assign a value to all benefits. In these cases, we recommend developing a narrative that can be used to describe the benefit. A good starting point is the narrative from Step 2 in this process.

7. **Interpret the estimates.** Values from benefit transfers retain the attributes of the source studies. It is important to provide the contextual interpretation of the estimated values.

8. **Step back and assess validity.** Once the estimates are available and have been interpreted, it is important to take a step and assess the estimates for their validity. Are the estimates believable? Do they make sense? Once again, an economist can assist in putting the estimates into perspective.

9. **Add up where possible.** In many cases, benefit transfer estimates cannot be added together due to the potential for double-counting. In some cases, adding up will be possible and adding them together is a good idea in those cases. However, when the estimates cannot be added together, we recommend presenting them as separate lines in a table with a full description of their interpretation.

10. **Compare to costs.** The final step is to compare the estimated benefits to the costs of the restoration work. We recommend caution here for a number of reasons. First, as we noted in the guidelines, benefit transfers will contain some level of error. Thus, a basic cost-benefit comparison (e.g., does the estimated benefit exceed the cost?) does not work well for benefit transfers. As we noted above, benefit transfers may be more useful in comparing across restoration projects in which case comparing the ratio of benefits to costs may be a useful metric. Second, as noted in Step 6, not all benefits may be included in the quantitative estimates. There may also be missing cost components as well. Thus, any set of estimated benefits should be used with caution and should be considered as one piece of information to use in making a decision.