5. Mapping Resources to Economic Value Generation

The resources and infrastructure described in section 3 can be thought of as inputs to ecological processes and economic activities that generate the value (wealth) described in section 4. Understanding how resources and infrastructure contribute to economic value is important because one aspect of ocean planning is to ensure that ocean resources are managed and used in a way that benefits the people of the region and the nation. A common way to measure that benefit is to quantify the economic value generated from the resources. This section describes what is known about the links between Northeast region marine resources and value generation, and how that information can be used in the planning process.

As discussed in the introduction to section 4 above, economic value exists only in the context of human populations and societies. One important determinant of economic value, therefore, is the people who participate in and receive benefits from the economic activity. The market and non-market value generated from marine resources in this region is, in part, a function of how many people live, work, and play in Northeast coastal and ocean areas, and how many visitors and tourists come to the region. There are some exceptions to this, especially in the more basic categories of ecosystem service values. For example, the value of carbon dioxide (CO_2) uptake by the coastal and ocean waters of the Northeast is largely independent of the region's population. But most categories of value will rise and fall with the number of participants; and that number can change because of population trends, changes in tourism, changes in recreational preferences, changes in wealth distribution, and other socioeconomic factors. Of particular interest to ocean planning, an increase in the number of participants in an economic or recreational activity, such as shellfish farming or recreational boating, often increases the demand for marine resources (e.g. coastal waters) and infrastructure (e.g. boat ramps, docks, marinas). That increase in demand can contribute to conflicts that ocean planning seeks in part to address.

5.1. Economic activity and ecosystem services

The economic values reflected in the NOAA ENOW data and used in much of section 4 to describe the Northeast region's ocean economy are "market" values measured or estimated from prices and quantifies of goods and services traded in markets. As mentioned in section 4, marine resources and activities can also generate values that affect human wellbeing but are not measurable in market transactions. These include the non-market or intrinsic values derived from walking on a beach, for example, and a range of other values sometimes referred to as "ecosystem service" values. There is some overlap between ecosystem service values and market values: for example, the primary production that supports biological populations of food fish is an ecosystem service, and its value is (partially) reflected in the commercial fisheries landings data.

The Millennium Ecosystem Assessment (MEAB 2003) framework suggests the following classification of ecosystem services derived from coastal and marine resources:

- Provisioning Services
  - Food (fisheries, aquaculture)

    - Sea water
    - Biochemical and genetic resources
    - Minerals and other physical resources
- Regulating and Supporting Services
    - Climate regulation (CO_2 uptake, heat exchange)
    - Water purification (filtration, dilution)
    - Flood/storm protection
    - Erosion control
    - Waste assimilation
    - Nutrient cycling
    - Primary production
- Cultural Services
    - Beach recreation and coastal access
    - Recreational boating, fishing, diving
    - Aesthetic, spiritual, and cultural uses of the coast and ocean
    - Existence/bequest value of local species (value attributed by people to knowing that species exist, and will survive for future generations)

Table 9 illustrates how different subsets of the Northeast region's marine resources and infrastructure (section 3) contribute to economic value generated in different segments of the Region' marine economy (section 4) and to three other major ecosystem service functions (climate regulation, water purification, and storm surge regulation) that are not captured by market data. The table is not exhaustive, but illustrates two important points. First, each natural resource and infrastructure component typically supports value generation in a variety of economic sectors and ecological functions. And second, different ocean economy sectors depend on different combinations of resources and infrastructure.

	Natural Resources/Habitats						Infrastructure					
	Ocean waters	Coastal waters/bays	Beaches	Wetlands/estuaries	Living resources	Cultural/archaeological resources	Shoreline structures	Commercial ports	Commercial real estate	Naval and Coast Guard facilities	Marinas	Residential real estate
Commercial fishing	X	X		X	X			X				
Aquaculture		X			X			X				
Seafood processing								X	X			
Seafood markets									X			
Recreational boating & fishing	X	X	X	X	X	X					X	
Beach recreation			X									
Tourism	X	X	X	X				X	X		X	X
Maritime transportation	X	X						X	X			
Ship- & boat building/repair	X							X	X	X		
Marine construction & manufacturing							X	X	X	X	X	X
Ocean energy	X	X						X				
Research and education	X	X	X	X	X	X		X	X			
National security	X	X						X		X		
Climate regulation	X	X		X	X							
Water purification		X		X								
Storm surge regulation		X	X	X			X					

Table 9 Mapping resources to economic sectors

5.2. Ecosystem service values and production functions

Although we know in principle which resources are used as inputs to which categories of ecosystem service and value, as suggested by Table 9, our ability to predict how changes in resources and infrastructure might affect value generation is, in most cases, incomplete at best. That is because the relationship between inputs (natural resources, infrastructure) and outputs (e.g., seafood, or recreation days) and the value of those outputs is often complicated. For some economic activities, the simple existence of access to a category of resources is sufficient: for example, the maritime transport industry needs port infrastructure and access to coastal and ocean waters to generate value; but that value does not increase, as a rule, when coastal water quality is improved. Furthermore, different areas of the open ocean may have different levels of value to the maritime transportation sector, depending on their location relative to preferred shipping routes. On the other hand, the value generated by activities such as commercial fishing, aquaculture, and recreational boating and fishing depends both on the quantity **and quality** of coastal and ocean water resources.

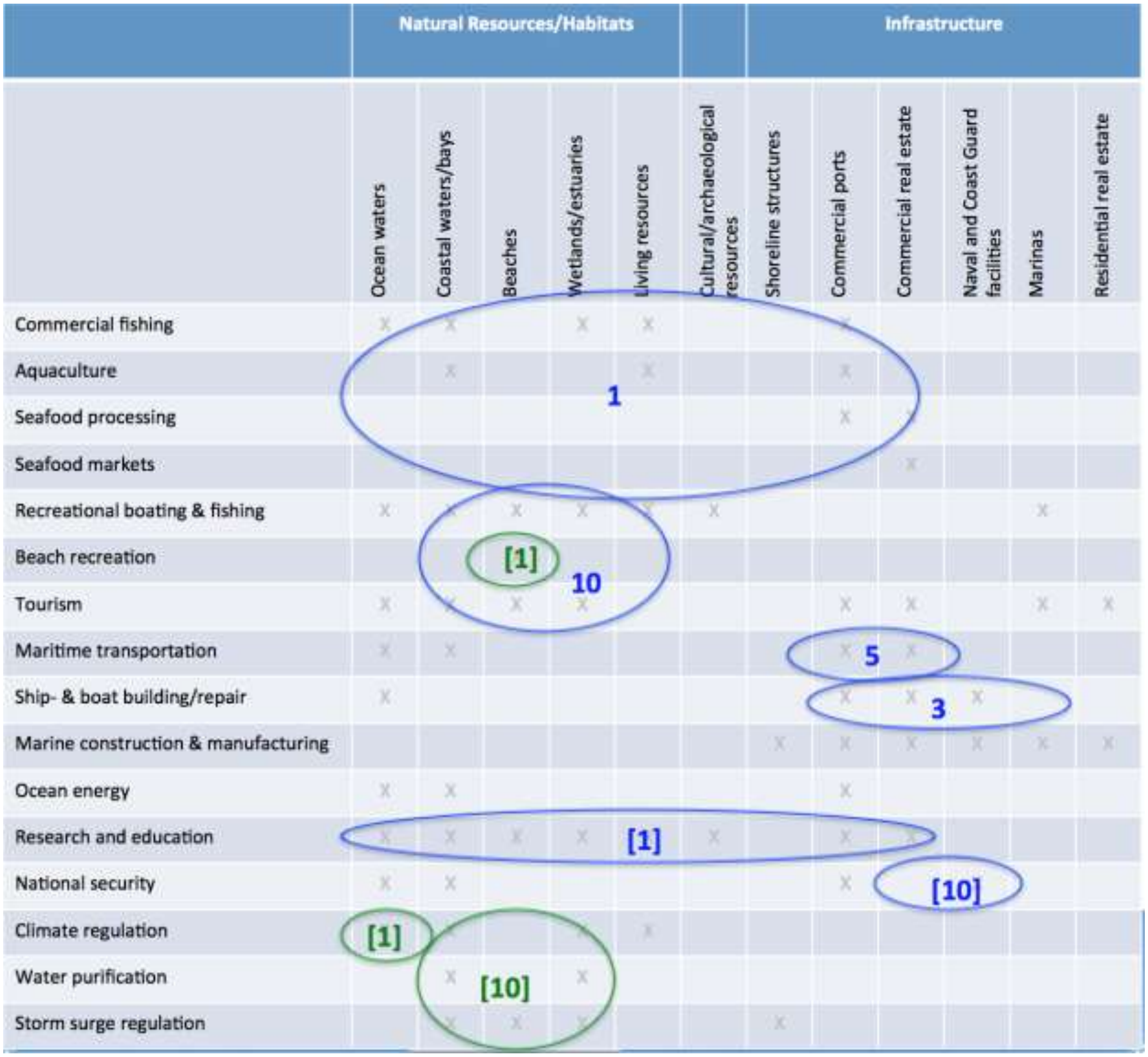
In general, the economic value of a resource or infrastructure component is best estimated at the margin, that is, in the context of a question such as “what is the value of **an additional square kilometer** of coastal wetlands to the Region’s seafood or coastal tourism industries,” or “what is the value of **an additional kilometer** of beach to Northeast coastal recreation”? The value per unit area of an incremental piece of marine habitat, for example, depends not only on the location and characteristics of that piece, but also on how much of that kind of habitat already exists in the regional ecosystem. For these reasons, estimates of unit value (dollars per square kilometer, or dollars per year per square kilometer) for natural resources should be treated with caution.

Most ecosystem service values cannot be observed from prices in markets, and therefore must be estimated by quantifying the ecological service produced (for example, tons of CO_2 absorbed by the ocean waters of the Gulf of Maine each year) and then applying a unit value (in this case, the cost imposed by adding a ton of CO_2 to the atmosphere – see EPA web pages on social cost of carbon). Published estimates of ecosystem service value from marine environments around the world span a very wide range, from near zero to more than $100 million per year per square kilometer ($1 million per year per hectare), depending on the location and the specific values included and assumptions used in the estimation. Using ecosystem service values in any particular planning context requires careful attention to the ways in which resources are used and valued, and the consequences of incremental management actions (Johnston and Russell 2011). Ecosystem service value estimates are broadly indicative of orders of magnitude for ecosystem services, but, as planning tools, they should be used with care.

Published work on Northeast ecosystem service value has focused largely on value associated with recreation, tourism, and seafood production. The highest value estimates for the Northeast Region come from recent ranges of estimates of total ecosystem service values for the Long Island Sound estuary and its beaches, seagrass beds, and coastal wetlands (Kocian *et al*. 2015). Northeast beach visits give rise to approximately $4 million/year/km^2 ($40,000/year/hectare) in ecosystem service value; and the Long Island Sound work estimates values as high as $10 million/year/ km^2 ($100,000/year/hectare) for seagrass beds and $20 million/year/ km^2 ($200,000/year/hectare) for coastal wetlands. These estimates are at the high end of values reported in the literature for marine resources around the world, particularly those for coastal wetlands, which range from $1,000 to $1 million/year/ km^2 ($10 to $10,000/year/hectare) (deGroot *et al.* 2012). An estimate of ecosystem service value from whale watching on Stellwagen Bank, based on a non-market (travel cost) model, is approximately $15,000/year/ km^2 ($150/year/hectare) (Hoagland and Meeks 2000).

The value of Northeast ocean areas for seafood production from commercial fishing averages about $1,200/year/ km^2 ($12/year/hectare), but ranges widely from near zero to more than \$50,000/year/ km^2 (\$500/year/hectare) for specific locations. Estimates of ecosystem service value associated with (hypothetical) open ocean aquaculture operations range from \$1 million to \$100 million/year/ km^2 (\$10,000 to \$1 million/year/hectare). See Appendix E for more detail on these and other ecosystem service value estimates for the Northeast.

Figure 49 summarize what is known about the major groups of market and ecosystem service value from coastal and ocean resources and infrastructure in the Northeast. The market value (GDP, \$billion/year) numbers in blue are drawn from section 4 of this report. The ecosystem service values in green are estimated from unit values drawn from the published literature (see list of references and Appendix E). The Northeast region encompasses about 1 million km^2 of open ocean water, 10,000 km^2 of coastal waters and bays, 1,000 km^2 of coastal wetlands, and 500 km of beaches. Applying the unit values (see above) to these areas results in estimates of on the order of \$1 billion/year in climate regulation from Northeast ocean waters, \$10 billion/year in supporting services (water purification, storm surge resilience, etc.) from coastal habitats, and \$1 billion/year in non-market recreational value from beaches (Figure 49). It is important to note that the benefits of climate regulation and supporting services such as water purification accrue in part to people outside the Northeast region.



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Aquaculture		X			X			X				
Seafood processing								X	X			
Seafood markets									X			
Recreational boating & fishing	X	X	X	X	X	X					X	
Beach recreation												
Tourism	X	X	X	X				X	X		X	X
Maritime transportation	X	X						X	X			
Ship- & boat building/repair	X							X	X	X		
Marine construction & manufacturing							X	X	X	X	X	X
Ocean energy	X	X						X				
Research and education	X	X	X	X		X		X	X			
National security	X	X						X				
Climate regulation		X		X	X							
Water purification		X		X								
Storm surge regulation		X	X	X			X					

Figure 49 Major categories of market and ecosystem service value generation
Estimates of market economy value added (GDP) in blue and ecosystem service value in green, both in billions of dollars/year. [Brackets] denote an order of magnitude estimate. See text above for details.

5.3. Use of economics in planning processes

It is the interrelationship between uses and resources illustrated in Table 9 that sometimes gives rise to conflicts between competing users of common resources in the coastal ocean. Some resource uses are compatible with each other in a specific location, implying that the values they can generate in those use sectors are additive; some are incompatible, implying that some values may be diminished or obviated when resource uses overlap. For example, shellfish farming on the bottom of a coastal bay may be compatible with recreational boating, allowing both food production and recreational values to be generated, whereas finfish farming with sea surface cages and mooring systems in that same bay might interfere with and largely preclude recreational boating.

Planning decisions can affect resources, infrastructure, and value generation in a variety of ways. Planning decisions may affect the quantity and/or quality of a resource or infrastructure category, or how it is distributed geographically (an historic example is the decision to improve water quality in Boston Harbor). Planning decisions may also affect access to resources and infrastructure, and the extent to which they are available as inputs to different economic sectors (for example, allocation of coastal ocean space to aquaculture could, in some cases, reduce access to that space by recreational boaters). By affecting the quantity, quality, and availability of resources for different uses, planning decisions affect the future generation of market and non-market (ecosystem) values.

Where use conflicts arise and resource uses are not compatible, legal systems, resource management policies, and planning decisions will affect how those conflicts are resolved and which use(s) have priority over others in each location. Including information about the economic consequences of different resource allocation and planning decisions can help ensure that marine resource management in the Northeast results in outcomes that are economically efficient and equitable.

5.4. Gaps in present knowledge

Incorporating economic information into planning decisions is difficult when available knowledge about ecosystem service production and value is incomplete. Details on the calculations for each of the uses reported here and some of the issues that arise can be found in Appendix E, along with a discussion of the significant gaps in present knowledge about ecosystem service values. These gaps include:

- Incomplete coverage – limited number of studies of Northeast ecosystem services and values
- Influential studies – incomplete coverage leads to excessive reliance on the few studies that have been performed
- Emerging future uses – new and emerging uses of coastal and marine resources can give rise to values that are not captured in most published studies
- Spatial and temporal variability – habitat and resource values can vary greatly between locations; this is often not captured well when a single unit value is applied
- Estimating unit values is difficult – reliance on survey methods to estimate non-market unit values requires significant effort to generate credible estimates
- Relationships and threshold effects – the relationships between quality and quantity of natural resources, and the value they generate, is often complex and not easy to model; and in particular, as resources are heavily used or degraded, there may be ecological thresholds at which a small change in economic activity can have large effects on resource values
- Passive uses unstudied – very little work has been done to understand “passive use” values such as carbon sequestration in marine vegetation and filtration of runoff