A Policy Analysis of the Use of Ecosystem Service Values in State and Local Decision-Making:

Potential Policy Questions and Gaps Analysis

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SECTION 1: INTRODUCTION

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 (Moberg & Folke, 1999). Examples include provision of clean water and clean air, maintenance of livable climates (carbon sequestration), pollination of crops and native vegetation, as well as 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 (Dore & Webb, 2003; Olsson 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 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.

The value of coastal ecosystem services, and the natural assets that provide them, has often been overlooked when making decisions about resource use, not because of a lack of importance, but because these goods are freely available rather than bought and sold through markets (Vaze, Dunn, & Price, 2006). Since many of the benefits derived from ecosystem services, and the related costs of degradation or impacts, are often not part of the traditional economy or traded in markets, many ecosystem services are frequently not recognized or considered, and are even neglected when decisions are made. They are off the ledgers of the public and policymakers, taken for granted, and yet nonetheless prized once made scarce (Brander, Van Beukering, & Cesar, 2007; Yang, Chang, Xu, Peng, & Ge, 2008). This contributes to the gradual erosion of some of the essential, communal life support services such as climate regulation, carbon storage, cultural heritage, aesthetics, erosion protection and waste disposal. Explicitly accounting for these benefits, using a range of economic and non-market metrics would reveal hidden costs and benefits to many current practices and yield decisions that most readily reflect the true value of the natural environment to society.

Society's affinity towards using and enjoying coastal environments dictates that coastal ecosystems must be managed in a complex arrangement for both protection and use. Therefore, the primary management goal now focuses on how to maintain specific ecosystem services for future generations while allowing the current generation to use and benefit from them. An ecosystem services approach moves beyond how people affect ecosystems to include how people depend on, and benefit from ecosystems. This reflects an important change in our thinking in terms of management goals. We have moved from a preservation perspective in which humans (and society at large) are perceived to interact with the natural environment in a one-way direction (i.e., we negatively impact it) to a two-way interactive direction in which society derives various benefits from the environment, but with trade-offs and at some environmental cost. Today, it is more an issue of what ecosystem services does society want with what tradeoffs and at what costs. The concept of ecosystem goods and services has become central to the discussion about the dependence of humans on nature and what that means both socially and economically (Costanza & Farley, 2007).

Under this project, NOAA has asked Eastern Research Group, Inc. (ERG) and its subcontractor East Carolina University (ECU) (hereafter, the ERG Team) to (1) review the current state of databases that provide information on estimated monetary values of ecosystem services, (2) identify policy questions that could be answered using the estimated monetary values of ecosystem services based on a review of laws and policies at the state or local level, and (3) identify the gaps that exist in answering those policy questions using the existing databases. To accomplish these objectives, the ERG Team performed a number of tasks. First, ECU took the lead on reviewing the existing databases and documented this work in a report to ERG. The ECU report provided a detailed assessment of 35 databases and related tools. Second, ERG held discussions with a select number of states and performed a detailed review of documents and policies from three states (Hawaii, Massachusetts, and North Carolina). ERG also facilitated a discussion on use of ecosystem service values in decision-making with a set of state managers during NOAA's annual state managers meeting in Silver Spring, MD in early 2013. This review led to identifying a general set of policy questions that could be answered using estimated values of ecosystem services. Finally, ERG compared the information available from the databases to the information needed to answer the policy questions from each state to identify gaps between the types of policy questions that can be answered and the existing studies cataloged in databases. In other words, are there sufficient studies to use to answer the policy questions we identified?

This report summarizes the results of this work. We begin by summarizing the work we did to identify policy questions that ecosystem service values can be used to inform policies and decisions. Next, we review the databases that have compiled monetary estimates of ecosystem service values. Following our review of the databases, we discuss the gaps that exist in providing answers to the policy questions we identified. To conclude the report, we provide a more detailed discussion of how monetary estimates of ecosystem service values can be used to address two specific issues: managed retreat and climate change adaptation planning.

SECTION 2: POLICY QUESTIONS

This section discusses ERG's work into identifying the policy questions that can be answered using monetary estimates of ecosystem service values. To develop this list of policy questions, ERG:

- Reviewed literature on ecosystem service valuation
- Participated in a roundtable discussion related to ecosystem services in New Hampshire on February 13, 2013
- Participated in a meeting with state managers on February 28, 2013 to discuss the use of ecosystem service values in public policy and decision making
- Interviewed five individuals working in three different states (Hawaii, Massachusetts, and North Carolina)
- Reviewed documents from each of the three states that define coastal policy in the three states.

The policy questions we have identified begin with three general questions that can be addressed by monetary estimates of ecosystem service values. These general questions flow from the nature of the estimates being economic values; that is, they deal with assessing incremental changes in an ecosystem (e.g., a condition, resulting from management alternatives, trade-offs between development and conservation). Following our presentation of the general questions, we identify more specific questions for the three states we reviewed in more detail that fit within the structure of the three general questions.

Our review of the policies within the three states found ample evidence that ecosystem service values would be a useful component in decision-making and policy analysis. Given the limited number of states (three) in our detailed interviews, the information we have included in this report on policy questions is meant to be illustrative rather than comprehensive. Our choice of examples in this report is intended to show different ways in which the monetary values can be applied. For example, we discuss use of economic values to address permit review in North Carolina, but we do not address permits explicitly in Massachusetts.[1] To be sure, economic values can be used to assess permits in Massachusetts also, but since we addressed the issue in North Carolina we turn to other issues in Massachusetts.

2.1 General questions

Our review of ecosystem service valuation literature and our discussions with states indicates that three general questions that can be addressed by ecosystem service values:[2]

- What is the total *economic* value of the services provided by a specific ecosystems?
- What is the economic trade-off between ecosystem conservation and development option(s)?
- What is the economic trade-off between different (non-development) uses of an ecosystem?

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[1] We do, however, address "federal consistency review" in Massachusetts which involves state review of federally-issued permits.

[2] We cannot, however, take credit for this typology; the ecosystem service value literature makes this grouping explicitly and implicitly in places.

Given that monetary values or ecosystem services are economic values, they must deal with trade-offs at some level. The second and third question explicitly deal with trade-offs in specific decision-making contexts. The first deals with trade-offs in a more implicit manner. In the context of economic value estimation, the total economic value of an ecosystem would come from estimating the value of an incremental change in the ecosystem with the value being phrased as a trade-off. For example, what would stakeholders be willing to pay to return to a storm-damaged wetland to a better state?

The total *economic* value of the services provided by an ecosystem should be distinguished from the "total value of an ecosystem" concept. In a well-cited study, Costanza et al. (1997) provided an estimate of the value of world's ecosystem services. The Costanza study was criticized by economists on a number of grounds. One of the key criticisms was that they had estimated the "total value" of the ecosystems, making no reference to an incremental change in the services being provided to derive the value.[3] Their resulting estimate was larger than the total world gross domestic product (GDP) at the time. Since GDP reflects income, their estimate indicated that we should be willing to pay more than we actually have for ecosystem services, a logical inconsistency. In our first policy question, however, we are interested in the "total economic value" (TEV) of an ecosystem. TEV is the sum of different ecosystem service values for a specific ecosystem reflecting the same incremental change in the ecosystem. For example, an economist might look at a specific change in a wetland (e.g., allowing a specific area to be developed, restoration after a storm) and look at the value associated with that change for different ecosystem services. If the economist uses a valid method to value the changes in each service, a total economic value can be estimated by summing the values for each service. There are complications that the economist needs to account for, such as the relationships between different ecosystem services.[4] Another not insignificant complication, would be to define the incremental change in a way that is meaningful to all of the services being valued. Nevertheless, studies have been done to estimate the TEV of specific ecosystems.

The "total value" of an ecosystem concept, however, has some appeal among the state policy makers we talked with. Specifically, the individuals we talked with indicated that understanding the total value of services produced by an ecosystem (e.g., wetlands) would provide useful input into policy discussions. As noted, there are issues with the "total value" concept. In response to this need from policy-makers, however, we have included the first general question that covers the TEV of an ecosystem. TEV is distinct from the total value concept, but, in our opinion, addresses the spirit of policy-makers' needs in this area; to be able to provide stakeholders and constituents with a sense of the value of a specific ecosystem.

Finally, the three questions we have developed are not necessarily mutually exclusive concepts. For example, TEVs can be used to assess trade-offs in the spirit of the second and third questions.

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[3] Furthermore, given that they were interested in valuing all ecosystems, an "incremental change" that would have applied to all ecosystems equally would have been meaningless.

[4] Another complication is when the study covers some (or most) services, but not all services in an ecosystem. In that sense, the name "total economic value" is something of a misnomer since not all services are valued. Nevertheless, the overall concept remains valid: defining an incremental change in an ecosystem, estimating the value of that change for specific services, and then adding up the values for the different services.

2.1.1 Total Economic Value of an Ecosystem

Ecosystem service values can be used to provide a total economic value for an ecosystem. For policy-makers, this would provide valuable information that can be used to justify policies and to provide information to stakeholders. For example, having TEV for several different wetlands in a state can help justify policies to continue to or expand protections of the state's wetlands.

The purpose of the question in this sense is to provide *information* (and outreach) to stakeholders, rather than to provide input into a specific decision. Using the economic values of ecosystem services in this way would allow policymakers to better inform their stakeholders about the value of various services provided by ecosystems. This role of ecosystem service values can be particularly useful in the case of services that generate non-market values which, by definition, tend to less "visible"; however, stakeholders may also be unaware of the market value of some ecosystem services.

There are a number of reasons why policy makers may want to educate stakeholders on the values of specific services. First, where the service translates into market value (e.g., fishery habitat for wetlands) stakeholders may not fully understand the linkage between the ecosystem service and the ultimate market value created. For example, the stakeholder may not understand the extent to which a wetland contributes to the fishery sector or not even understand that a wetland is a contributor. A similar argument can be made for wetlands as storm protection. Second, in the case where the service has a non-market value, such as aesthetics, stakeholders are most likely unaware of the value given it does not manifest itself in a market setting.

One concern expressed by policy makers that we talked with was to be able to secure and keep the support of stakeholders for environmental objectives. Providing stakeholders with information on the TEV of different ecosystem services may potentially improve stakeholder support for policies to preserve these services.[5]

2.1.2 Addressing Trade-Offs between Development and Ecosystem Services

As noted, the economic values of ecosystem servicess are very well suited at addressing trade-offs. One trade-off highlighted in our discussions with states and during the February 28th meeting is the trade-off between ecosystems and development. For example, a local government may be faced with a decision on whether to allow development on part of salt marsh. The development project will result in some level of economic benefit, but salt marshes provide significant ecosystem services. Presumably the economic value of the development project in terms of the producer and consumer surplus can be estimated. To assess the trade-off, it would be necessary to determine the loss in ecosystem services from the development project and then to place value on the loss using the values of those services. A full comparison of the two options would have to include appropriate discounting of future benefits (from both options) to allow for a valid comparison between the two.

An area that places development considerations against ecosystems is storm protection. During the winter of 2012-2013, Massachusetts was hit by a number of storms that resulted in significant damage to

[5] Policy makers, however, also observed and recognized the opposite could also occur: providing these values could lead stakeholders to reduce their support for preservation of ecosystems.

coastal properties, most visibly in the Plum Island area.[6] Gray engineering projects such as a sea wall could, potentially, protect the homes along the shore. However, sea walls will result in the reduction of dunes which provide a number of ecosystem services (including storm protection benefits). Economic values of ecosystem services can be used to assess the option of building sea walls compared to other options. In this situation, it would be necessary to account for (1) the probability that the sea wall would fail for given storm intensities, (2) the protective benefits (and likelihood of failure) for other protective measures (e.g., dunes) for given storm intensities, and (3) the distribution of benefits[7] and (4) the distribution of negative impacts (costs—both monetary and non-monetary) of both.

During our discussions with states, including during the February 28th meeting, state officials indicated a concern that this type of comparison may result in the ecosystem "losing out" in the assessment. That is, the development options may result in a larger economic benefit compared to preservation of an ecosystem. In theory, however, the government could extract an economic rent (possibly in terms of a tax or fee) from the development project equivalent to the difference in benefits.[8,9] If such a rent could be extracted, even partially, from the development project, those funds could be used to enhance another ecosystem to offset the loss in services.[10]

Developing estimates of the ecosystem service values to compare to the development option, however, requires resources. Using benefit transfer methods would reduce those costs.[11] However, estimates of ecosystem services transferred from other areas may not be accepted as valid by officials and decision-makers in the place where they would be applied. Nevertheless, not all development projects involve original estimates of the benefits. In some cases, multipliers for a development project are taken from other studies or are based on "benchmark" values. A useful distinction is between "original" measures and "relevant" measures. An original measure is one estimated for the specific project while a relevant one would be an estimate that can be reasonably applied to estimate benefits. The distinction between "original" and "relevant" is equally applicable to both the benefits of the development option and the value of ecosystem services. Use of "relevant" estimates in each case should result in valid comparisons. ERG discussed the use of benefit transfers techniques with the three states we talked with. North Carolina cast doubt on their acceptability in that state while Massachusetts and Hawaii both indicated there would be some level of acceptability to use of transferred estimates.

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[6] http://www.bostonglobe.com/metro/2012/12/28/storm-damages-four-beachfront-homes-plum-island/l4tvMtDxSMSo7SDYp1YXGL/story.html.

[7] Sea walls provide benefits to those along with property along the shore. The ecosystem services of dunes, however, may provide benefits to a broader population.

[8] This would be similar to a payment for ecosystem services (PES) approach to providing incentives.

[9] In fact this is done under Massachusetts General Law (MGL) Chapter 91 (filled tidelands) where previously filled coastal tidal areas (including salt marshes) are considered part of the common wealth and therefore developers who propose projects need to "lease" the rights (and pay fees for those rights) to occupy the land even though they legally own it. However, the fees to lease the land were not set using ESVs.

[10] The rent that is extracted could also work to make the development project less attractive and result in conservation.

[11] Benefit transfer is the process of taking values of ecosystem services estimated in certain geographic areas (study sites) and applying them to the area of interest (policy site) following some adjustments to ensure that they are relevant to the area where they are being applied. Benefit transfer is discussed in more detail in Section 4.1.

2.1.3 *Addressing Trade-Offs Between Different Ecosystem Services*

A second use of ecosystem service values in tradeoffs is to use them to compare two different ecosystem-related options. For example, an oyster reef restoration project is likely to result in significant benefits;[12] however, if that reef is constructed in place (or on top of) another ecosystem such as a salt marsh or a beach, then the services of the other ecosystem could be lost. This type of trade-off analysis may be less problematic to environmental managers since it does not involve loss of ecosystems, but rather the "best" use of a particular land or coastal area. In particular, this type of policy question is one where environmental managers are deciding among alternative paths. Similar arguments can be made for this type of general question related to use of "original" versus "relevant" estimates. That is, development of original estimates may be costly and use of "relevant" ones may be necessary.

Ocean planning is another excellent example of assessing trade-offs between different ecosystem services. In developing ocean plans, state and federal officials need to examine all the uses of ocean waters and attempt to minimize conflicts between them. Decisions need to be made about where certain activities (wind energy facilities, ocean floor cables, LNG terminals, etc.) should be encouraged or discouraged. Boating, fishing, whale watching, national defense, commercial navigation, ocean sanctuaries for endangered species, migratory shorebird flyways are all ocean uses that can be assessed in terms of spatial and temporal distribution. The difficulty comes in assigning values to them in attempting to decide which areas are most suitable for each, and which combinations can co-exist.

2.2 North Carolina

For the state of North Carolina, ERG discussed the use and usefulness of ecosystem service values with a state official and we reviewed a series of documents from the state, including:

- The Coastal Area Management Act (CAMA) – CAMA provides the overarching law for the state governing North Carolina's coastal areas.[13]
- The Coastal Management section of the North Carolina Administrative Code (NCAC) - This chapter of North Carolina implements CAMA.[14]
- North Carolina Department of Coastal Management's (NC DCM's) "Technical Manual for Coastal Land Use Planning"[15]
- The "CAMA Handbook for Development in Coastal North Carolina"[16]

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12 http://www.habitat.noaa.gov/partners/toolkits/restorationjobs/alabama/economic_reports/oyster_restoration_study_gulf_of_mexico.pdf.

13 http://dcm2.enr.state.nc.us/Rules/cama.htm

14 http://reports.oah.state.nc.us/ncac.asp?folderName=\Title%2015A%20-%20Environment%20and%20Natural%20Resources\Chapter%2007%20-%20Coastal%20Management

15 http://dcm2.enr.state.nc.us/planning/techmanual.pdf

16 http://dcm2.enr.state.nc.us/handbook/contents.htm

CAMA provides a number of areas we could review for use of the economic values of ecosystem services. Our focus in this report however will be on development of local land use plans under CAMA and permits for development in areas of environmental concern (AECs). These two areas form the backbone of CAMA. Prior to reviewing these two areas for North Carolina, we review the overarching goals of CAMA.

2.2.1 Overarching CAMA goals

CAMA has a number of overarching goals. We identified three passages in the Act that appear to provide some scope for the use of economic valuation in policy making under CAMA (emphasis added by ERG):

- "To insure that the **<u>development or preservation</u>** of the land and water resources of the coastal area proceeds in a manner consistent with the capability of the land and water for **<u>development, use, or preservation</u>** based on ecological considerations" (CAMA Section 113A-102(b)(2)).
- "To insure the orderly and **<u>balanced</u>** use and preservation of our coastal resources on behalf of the people of North Carolina and the nation" (CAMA Section 113A-102(b)(3))."To establish policies, guidelines and standards for:
    - a. Protection, preservation, and conservation of natural resources including but not limited to water use, scenic vistas, and fish and wildlife; and management of transitional or intensely developed areas and areas especially suited to intensive use or development, as well as areas of significant natural value;
    - b. **<u>The economic development of the coastal area</u>**, including but not limited to construction, location and design of industries, port facilities, commercial establishments and other developments" (CAMA Section 113A-102(b)(4)).

The first goal indicates the need for ensuring development decisions have some basis in ecological considerations. The second goal then indicates the need to balance use and preservation of coastal resources. We see the use of the word "balanced" as indicating that some consideration of relative economic values could take place under CAMA. Finally, the third goal we called out indicates that the Act should establish policies, guidelines, standards for development in the coastal area. We expect that, combined, these three goals provide some scope for the use of economic values of ecosystem services in guiding how North Carolina controls development under the Act.

2.2.2 Land Use Plans

CAMA requires the development of local land use plans for coastal counties defined under the Act.[17] The plans are intended to implement the overarching goals of CAMA and are meant to guide local governments in balancing development and preservation of ecosystems. The requirements for the plans are described in detail in 15A NCAC 07B.0700. For the most part, the requirements proscribe what the plans must address without indicating how the local governments (counties and/or municipalities) should address specific issues. Nevertheless, the rule does indicate clearly that the plan must not contradict or be in violation of state or

[17] http://dcm2.enr.state.nc.us/cama_counties.htm

federal laws. In particular, the plans must address six "Management Topics" specified by the NC Coastal Resource Commission (CRC):[18]

- Public Access
- Land Use Compatibility
- Infrastructure Carrying Capacity
- Natural Hazard Areas
- Water Quality
- Local Areas of Concern

Our review of land use plans in relation to ecosystem service values focused primarily on the second, land use compatibility. This management topic deals with development most directly. The Technical Manual for developing plans defines this management topic as "management of land use and development in a way that minimizes its primary and secondary impacts on natural and man-made resources." If a local land use plan is determined to have a negative impact on a management topic, the local government must specify a mitigation plan to alleviate those impacts. In the plans, local governments must determine a land classification scheme and then to specify appropriate uses for different land types. Within this classification scheme, some uses (e.g., development) can be restricted or prohibited for certain land types, while other land types can have fewer restrictions.

There appears to be some scope for the use of the economic values of ecosystem services in land use plans in North Carolina. There are two elements that are required for the plans that are relevant (emphasis added by ERG):

- Under the "Plan for the Future" element, in relation to future planning for land use compatibility one of the planning objectives is "[a]dopt and apply local development policies that **balance** protection of natural resources and fragile areas with economic development" (15A NCAC 07B.702 (d)(3)(B)(ii)(I)).
- Under the "Tools for Managing **Development**" element of the plan, the rule indicates that "[t]his element of the plan provides a description of the **management tools** that the local government selects and the actions to be taken to implement the CAMA Land Use Plan" 15A NCAC 07B.702 (e).

From our reading, it appears that both of these indicate that consideration of the value of ecosystems services relative to that of development (i.e., assessing trade-offs between development and ecosystems) can be used in the local land use plans. Specifically, the first element we list above (for future planning) involves balancing protection of coastal resources with development. The second element indicates that local governments can specify which tools can be used to management development, leaving open the possibility of using economic valuation of ecosystem services in land use plans. Furthermore, in the Technical Manual for developing the land use plans, the NC Division of Coastal Management defines policies as "a consistent set of

[18] Whereas the NC Division of Coastal Management is charged with implementing the requirements of the law, the CRC is responsible for developing the guidelines for the land use plans.

land use and development principles and **decision guidelines** or courses of action, adopted by the elected board, that are planned to attain the local government's goals and objectives" (NC DCM, 2002, p.69; emphasis added by ERG).

Thus, in this sense, ERG sees some scope for using the economic values of ecosystem services as a tool within North Carolina land use plans. However, despite the fact that the context is within comparing development to conservation (the topic of general question #2), we see this as more in the spirit of general question #1 which deals with providing information to stakeholders. County planners could use the economic values of ecosystem services as an indication of the economic value of specific ecosystem services within the county for specified changes in those ecosystem (e.g., a 10 percent loss of the ecosystem). This would provide information to better judge future development efforts within a county. For example, information on the value of specific services provided by wetlands would offer some counterbalance to the value of potential development that would degrade those services.

2.2.3 Areas of Environmental Concern and Permits

CAMA also required the identification of areas of environmental concern (AECs) and for the use of permits to control development within the AECs. The CRC defined four broad types of AECs:

- The Estuarine and Ocean System
- The Ocean Hazard System
- Public Water Supplies
- Natural and Cultural Resource Areas

For purposes of this report, we focused primarily in the estuarine and ocean system, ocean hazard system, and the natural and cultural resource areas types. The AECs in North Carolina cover almost all of the coastal waters and 3 percent of the land in the 20 counties defined as "coastal counties" under CAMA.[19]

Development within AECs is restricted to protect the fragile nature of these ecosystems and any development within an AEC must be covered by a permit. Under CAMA, there are three types of permits:

- Major – This permit covers large project that could potentially harm the coastal environment.[20]
- General – This permit covers projects with little or no impact on the environment.
- Minor – This permit covers projects for which major or general permits are not required.

The economic values of ecosystem services could prove useful in assessing major permits. As noted above, North Carolina must review and issue major permits for projects that could potentially harm the coastal environment. North Carolina could require permit applicants to estimate the economic value of their

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[19] http://dcm2.enr.state.nc.us/handbook/contents.htm, Section 2.

[20] From the NC DCM Handbook for Coastal Development, a major permit is required if the "project involves development in an Area of Environmental Concern and any of the following: (1) another state or federal permit, license or authorization, such as for dredging and filling, wetlands fill, (2) stormwater management, sedimentation control, wastewater discharge or mining; (3) excavation or drilling for natural resources on land or under water; (4) construction of one or more buildings that cover more than 60,000 square feet on a single parcel of land; (5) alteration of more than 20 acres of land or water. A major permit is usually required if there is any dredging or filling of water or marsh."

development projects. The permit applicant must currently identify the impact on the environment from the project. Thus, the state could compare lost value to the ecosystem (using economic valuation of the lost ecosystem services) to the value projected to be created by the development project.[21] This is not to say that the development project's economic value should exceed the lost value to the ecosystem, but this comparison would allow the state to conduct a more thorough analysis of costs and benefits to assess whether the project should be allowed. If such a system were put in place for making permitting decisions, it is important to note that regulatory standards would need to be established as the basis for such an analysis to withstand legal challenge.

2.3 Massachusetts

For the state of Massachusetts, we reviewed the Office of Coastal Zone Management's *Policy Guide* document.[22] This document "presents the official policies of the Commonwealth's coastal program" (*Policy Guide*, p. 1). From this document, we were able to identify numerous areas where ecosystem service values would be useful in assisting the state in making decisions and assessing coastal policy. Our focus in this report, however, will be on two areas:

- Federal consistency review
- Coastal hazards policy

2.3.1 Federal Consistency Review

Under the Coastal Zone Management Act (CZMA), federal actions that are expected to have a foreseeable impact on state water or land must be consistent with the *enforceable* components of a federally-approved coastal zone management plan of that state. Under this authority, the state has the opportunity to review the federal actions that impact coastal resources to ensure that they are consistent with state policies. Federal actions that are covered by the consistency review component of the CZMA include: federal licensing or permitting activities, outer continental shelf (OCS) plans, federal agency activities, and federal assistance provided to state or local governments.

The Massachusetts *Policy Guide* provides a series of review steps and procedures related to different federal actions covered by the consistency review. The guide also identifies the data and information needed to perform a consistency review. Included in that information are (*Policy Guide*, page 12; emphasis added by ERG):

- "A detailed description and analysis of the project objectives and **anticipated benefits**"
- "A detailed description and assessment of the **negative and positive potential coastal effects** of the project including **direct and indirect resource and use impacts** from all aspects of the project, short-

[21] Future values of both the development project and the ecosystem services should be appropriately and consistently discounted to reflect the time value of money.

[22] MA Office of Coastal Zone Management (MA CZM), 2011. *Policy Guide*, October; http://www.mass.gov/eea/docs/czm/fcr-regs/czm-policy-guide-october2011.pdf.

term and long-term impacts for all phases of the project (e.g., acquisition, development, construction, and operation), and **cumulative impacts** of the project"

- "A description of measures taken to avoid, minimize, and mitigate adverse coastal effects"

ERG views these three types of data as providing the basis for using the economic values of ecosystem services to provide input into assessing federal actions. The "anticipated benefits" should include the economic benefits associated with the project. The second bullet indicates that the data should include an assessment of the coastal impacts (e.g., ecosystem service impacts). Finally, the third bullet provides for information to alleviate the coastal impacts.

Federal consistency requirements are a complex area under the CZMA. NOAA's Office of Ocean and Coastal Resource Management (OCRM) provides detailed guidance on its application and the complexities of the consistency review requirements.[23] The basis for assessing consistency is that the federal actions must be consistent with the enforceable state policies of the federally approved coastal management program of the state. Nevertheless, ecosystem service values can be used to assess impact in monetary terms. The *Policy Guide* states the following regarding assessing consistency:

> "To review federal actions to determine if they are consistent with the Massachusetts coastal program policies, the "coastal effects" of those actions must be assessed. The term "coastal effects" refers not only to environmental effects (i.e., impacts on biological or physical resources found within the state coastal zone), but also to effects on human uses, such as fishing and boating, public access and recreation, scenic and aesthetic enjoyment, and resource creation or restoration" (Policy Guide, page 4).

One enforceable component of the Massachusetts coastal policy is the state's policy for siting energy facilities in the coastal zone (*Policy Guide*, Energy Policy #1, page 30). This policy states:

> "For coastally dependent energy facilities, assess siting in alternative coastal locations. For non-coastally dependent energy facilities, assess siting in areas outside of the coastal zone. Weigh the environmental and safety impacts of locating proposed energy facilities at alternative sites" (Policy Guide, page 30).

Energy facilities can potentially create significant economic benefits and generate significant ecosystem impacts. The policy calls for having the entity wanting to site the facility to assess alterative coastal and non-coastal (if possible) sites for the facility.

The economic values of ecosystem services can be used in this type of assessment to determine where the impact of the facility would be greatest. For example, a project to site a facility that would impact the Massachusetts coastal zone would require consideration of at least two sites under the Massachusetts policy. Using ecosystem service values, each site could include a monetary estimate of the impacts on ecosystem services, including the details of which services would be impacted and the value of the impacts. This would allow for a more informed assessment of the siting decision.

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[23] http://coastalmanagement.noaa.gov/consistency/welcome.html.

2.3.2 Coastal Hazards Policy

During our discussion with Massachusetts state officials, we discussed recent events in the state related to coastal storms. During the winter of 2012-2013, a number of strong coastal storms hit the Massachusetts coastline causing significant levels of erosion and property damage. In particular, Plum Island was particularly hard hit with six houses being demolished/lost and several others being put in danger.[24] The nature of the conversation ERG had with the Massachusetts officials centered on storm impacts and ways to protect property impacted by storms. In light of that conversation, ERG decided to assess coastal policies in Massachusetts in relation of ecosystem service values.

The *Policy Guide* identifies four state policies related to coastal hazards (emphasis added by ERG):

1. "Preserve, protect, restore, and enhance the beneficial functions of storm damage prevention and flood control provided by **natural coastal landforms**, such as dunes, beaches, barrier beaches, coastal banks, land subject to coastal storm flowage, salt marshes, and land under the ocean."
2. "Ensure that construction in water bodies and contiguous land areas will **minimize interference with water circulation and sediment transport**. Flood or erosion control projects must demonstrate no significant adverse effects on the project site or adjacent or downcoast areas."
3. "Ensure that state and federally funded public works projects proposed for location within the coastal zone will:
    - Not exacerbate existing hazards or damage natural buffers or other natural resources.
    - Be reasonably safe from flood and erosion-related damage.

> "In addition to their ecological value, natural landforms in the coastal zone (barrier beaches, dunes, beaches, coastal banks, land subject to coastal storm flowage, salt marshes, and land under the ocean) provide significant protection from coastal storms, flooding, erosion, and relative sea level rise. Beaches, marshes, dunes, and land subject to coastal storm flowage dissipate destructive storm waves. Dune systems and coastal banks, particularly if stabilized by beach grasses and other binding vegetation, prevent direct wave attack against landward areas due to their elevation and ability to dissipate wave energy. Barrier beaches2 protect both mainland development and the salt marshes and other productive habitat between them and the mainland."
>
> "As impacts to property from storms, flooding, erosion, and relative sea level rise increase, there is, in turn, increased demand for the construction of protective structures, such as seawalls and revetments. In some instances, such structures have been effective and are necessary, particularly where natural buffers have been irrevocably lost, such as in urban areas. However, they are becoming increasingly recognized as expensive short-term solutions, which frequently exacerbate problems elsewhere along the coast and foster a false sense of security."
>
> "Coastal engineering structures are generally constructed along eroding shores or areas subject to storm damage from wave activity. As the high water line on an eroding shore migrates toward the engineered structure (such as a seawall, revetment, or bulkhead), the beach diminishes in volume and width resulting in the eventual loss of the beach and its protective functions, as well as loss of the recreational value of the beach and the public trust rights of fishing and fowling in the intertidal area."
>
> (*Policy Guide*, pages 19-20).

[24] http://www.nytimes.com/2013/03/19/us/in-path-of-storms-plum-island-mass-weighs-its-options.html?_r=0

- **Not promote growth and development in hazard-prone or buffer areas**, especially in velocity zones and Areas of Critical Environmental Concern.
- Not be used on Coastal Barrier Resource Units for new or substantial reconstruction of structures in a manner inconsistent with the Coastal Barrier Resource/Improvement Acts."

4. "Prioritize **acquisition** of hazardous coastal areas that have **high conservation and/or recreation values** and **relocation of structures** out of coastal high-hazard areas, giving due consideration to the effects of coastal hazards at the location to the use and manageability of the area."

In reviewing the discussion of these four policies in the *Policy Guide*, ERG interprets the first three as placing a high value on protection of ecosystem services. For example, under the first policy, the *Policy Guide* discusses the rationale for natural systems rather than engineered solutions for storm protection (see text box). The policy favors natural systems as a means of storm protection over engineered structures. In this situation, the ecosystem service value of beaches, dunes and marshes for storm protection benefits (as well for services other than storm protection) would provide the state with useful information. Having the value of these ecosystem services for specific areas or contexts would allow the state to (1) provide justification for a natural systems vs. engineered systems approach and (2) estimate on the ecosystem from adding engineered structures.

The fourth policy regarding acquisition of hazard areas and relocation of structures from those areas also represents an area where the economic values of ecosystem services can be used to guide decisions. Acquisition and relocation decisions (i.e., retreat) involve costs and would also result in some ecosystem services as land area is returned to the natural system. Furthermore, alternatives to retreat exist such as improving the natural system for storm protection or using engineered structures. For each option, the state could use ecosystem service values, combined with acquisition costs, to assess benefits and impacts to determine a preferred course of action. In fact the regulations that implement these policies contain presumptions of significance and performance standards that are based on functions and values of coastal ecosystems. The economic values of ecosystem services could be used in quantifying several of the ecosystem service functions that are currently not sufficiently protected because they are undervalued (e.g. coastal banks)

2.4 Hawaii

All of Hawaii is within the coastal zone which means that all policies and decisions related to the natural environment in Hawaii will impact the coasts. Reflecting this importance, Leo Assuncion of Hawaii indicated to ERG that the economic values of ecosystem services for the entire ocean resource would be useful including values reflecting various components of the ocean.[25] As noted in Section 2.1 above, a "total value of an ecosystem" is a problematic concept since there can be trade-offs among services in how value is produced. Nevertheless, Mr. Assuncion indicated this type of information would allow the state to make better informed decisions related to coastal zone management and better understanding the trade-offs faced by the decisions made by state agencies.

[25] A 2002 study estimated that the value of the Hawaiian coral reefs as $364 million annually ($2002); http://coastalsocioeconomics.noaa.gov/core/reefs/hicesar.pdf.

In addition to the discussion with Mr. Assuncion, ERG also reviewed a number of state documents including the state's Ocean Management Plan released in July.[26] The Plan provides the state's vision for managing its ocean resources while balancing economic growth worded as (emphasis added):

> "The vision for Hawaii's ocean resources is for **a healthy, productive, and sustainable ocean ecosystem** that **fosters economic growth** while preserving and protecting Hawaii's values and needs." (Page 1).

Thus, the vision itself recognizes the need for a balance between conservation and development. To be sure, a significant portion of Hawaii's economic development (e.g., tourism, fishing) depends on the ocean. This vision, however, also recognizes that trade-offs will exist between policy decisions. Based on this, ERG sees the vision of the Hawaii plan as laying out a basic structure for consideration of ecosystem service values in guiding decisions.

The Plan includes eleven management priorities and provides details on the background, status,[27] and targets for each objective. The first management objective identified in the Plan is "Appropriate Coastal Development." The background discussion for the objective includes the following consideration (Ocean Plan, page 23):

> "Appropriate coastal development addresses the issues identified under the CZM Act, including coastal hazards (including sea level rise), historic resources, coastal ecosystems, and Hawaii's economy for current and future generations."

Thus, the objective explicitly includes the need to balance ecosystem services ("coastal hazards (including sea level rise), historic resources, coastal ecosystems") with economic considerations. Within this objective, the state also included a set of qualitative targets. Two in particular would benefit from consideration of ecosystem service values: (1) managing retreat and (2) siting appropriately.

For the managed retreat target, the plan indicates that the state should develop "long-term planning and strategies to support managed retreat" (page 23). The plans and strategies formulated by the state could benefit from consideration of the economic values of ecosystem services. ERG expects that these plans would need to determine priorities (e.g., what to move and when). Using the economic values of ecosystem services could be considered in the prioritization process. Additionally, the managed retreat target includes consideration of relocation decisions and the use of incentive to property owners. Ecosystem service values can be used in setting appropriate incentives that balance property values with gains from ecosystem services.

The "site appropriately" target includes the following text (page 23):

> "Proposed projects/actions are evaluated during the land use entitlement process to determine the sufficiency of proposed adaptation measures and infrastructure durability over the lifetime of the project, **taking into account individual and public economic impacts**."

Thus, this target explicitly calls for balancing adaptation and durability against economic considerations.

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[26] http://planning.hawaii.gov/czm/ocean-resources-management-plan-ormp/.

[27] The July 2013 plan builds on the state's 2006 Ocean Plan and move the state's Plan into a "adaptation" phase where previous "demonstration" approaches are applied more broadly.

SECTION 3: REVIEW OF EXISTING DATABASES

> This section draws heavily from ECU's report to ERG, *A Policy Analysis of the Applications of Ecosystem Service Values: Ecosystem Services Valuation Databases* (Final Report, January 21, 2014),

ERG's subcontractor, East Carolina University (ECU), was tasked with performing a review of existing databases that contain estimates of the economic values of ecosystem services. This section summarizes the results of ECU's review. We begin by summarizing the databases that were identified and summarize ECU's review of these databases in terms of accessibility, ease of use, and content (Section 3.1). The ECU research also found that many of the identified databases were being merged into a single database directed by the Ecosystem Services Partnership (ESP) and The Economics of Ecosystems and Biodiversity (TEEB). Thus, Sections 3.2 and 3.3 provide additional details on the ESP and TEEB efforts. Section 3.4 provides some concluding thoughts on these databases.

3.1 Database Identification and Review

A total of 17 databases consisting of various categories, and 18 additional websites were identified within the initial stages of research (Tables 1 & 2). Seven of the 17 databases specifically referenced valuation studies and included the USA within their geographical scope (Table 1). Other types of databases and websites were also considered due to their relevance and potential use in understanding the current state of knowledge in terms of ecosystem services valuations (Table 2). Some of these databases contain tools and resources used to model how ecosystem service values associated with different activities change as the quality and quantity of marine resources is altered through different management scenarios (i.e., Invest, ARIES).

Initial research for this project began with databases that had been cited in the original scope of work for this project, including the Environmental Valuation Reference Inventory (EVRI) and ENValue. EVRI and EnValue are well-established valuation databases. They are primarily bibliographic databases with similar search processes, levels of organization, and references. Containing about 2,000 international studies, the EVRI database was last updated in 2011, whereas the ENValue database seems to have been ignored since 2004. Despite this disadvantage, EVRI and ENValue were easily accessible, easy to use, and contained large numbers of valuation references. For these reasons, they were used as a baseline for comparison. Each database was reviewed according to various factors of accessibility, ease of use, and content (Table 3).

Table 1 - Ecosystem Services Valuation Databases and Website Links Reviewed Under this Project

Databases With Geographical Scope That Includes U.S.A.	
Name of Resource	Web Host
GecoServ	http://www.gecoserv.org
EVRI *	https://www.evri.ca/Global/HomeAnonymous.aspx
Envalue *	http://www.environment.nsw.gov.au/envalueapp
Lincoln University *	http://www.lincoln.ac.nz/research-themes/ecosystem-services/Research-Projects-and-Websites/Ecosystem-Services-Valuation-Database
Marine ESP	http://www.marineecosystemservices.org
National Ocean Economics Program (NOEP)	http://www.oceaneconomics.org
Sportfishing Values Database *	http://www.indecon.com/fish

Databases with geographical scope that excludes U.S.A.	
Name of Resource	Web Host
EEPSEA	http://valuasia.eepsea.net
ValueBase SWE	http://www.beijer.kva.se/sida.php?id=44
Databases that are unavailable (As of December 2013)	
Name of Resource	Web Host
Beneficial Use Values	http://buvd.ucdavis.edu/buvd.web.pdf
Review of Externality Database	http://www.red-externalities.net
COPI	http://www.ecologic.eu/3106
ConservMap	http://consvalmap.org
Ecosystem Services Database (ESD)	http://esd.uvm.edu
ESVD	http:// http://www.fsd.nl/esp/80763/5/0/50
Nature Valuation	http://www.fsd.nl/naturevaluation/70976/5/0/30
SERVES	http://esvaluation.org

* Database appears to be outdated

Table 2: Additional Databases and Tools for Ecosystem Service Valuation

Useful Tools	
ARIES	http://www.ariesonline.org/resources/toolkit.html
EBM Tools Network	http://www.ebmtoolsdatabase.org
InVest	http://www.naturalcapitalproject.org/InVEST.html
MIDAS	http://www.seaplan.org/ocean-planning/tools-to-inform-decision-making/ecosystem-tradeoff-modeling/midas
Solves	http://solves.cr.usgs.gov
Multiple Benefits Toolbox and Carbon Calculator	http://www.un-redd.org/Multiple_Benefits_GIS_Mapping_Toolbox/
Coastal Capital Valuation	http://www.wri.org/project/valuation-caribbean-reefs/tools
Conservation Gateway	http://www.conservationgateway.org/Pages/default.aspx
Natural Capital Defense	http://www.naturalcapitalproject.org/database.html
EPA	http://www.epa.gov/research/ecoscience/eco-services.html
Earth Economics	http://www.esvaluation.org
Social Networks	
Ecosystem Commons	http://ecosystemcommons.org
ES Experts Directory	http://projects.wri.org/ecosystems/experts
Indicators	
ES Indicators Database	http://www.esindicators.org
Genuine Progress Indicator	http://rprogress.org/sustainability_indicators/genuine_progress_indicator.htm
Global Biodiversity Info. Facility	http://www.gbif.org
Nature Serve	http://www.natureserve.org
World Development Indicators	http://web.worldbank.org

Table 3: Criteria Used to Review Ecosystem Services Valuation Databases

Access to Database	Ease of Use	Content
• Finding the database • Availability • Registration or costs • Updated	• Navigation • Searching Capabilities • Home Page Visual Quality • Definitions • Help File or User Tutorial	• Number of references • Time Frame • Ecosystem Services coverage • Geographic scope • Types of values & methods • Access to publications

3.1.1 Accessibility

EVRI and EnValue were easily accessed through web links provided by a simple web-based search. To find other databases, the search term "ecosystem service valuation database" was entered into a series of web-based search engines to generate baseline knowledge of databases. If links, ecosystem tools, or additional literature were provided by the database under review, these were also examined.

Based on criteria for accessibility, most available databases are easy to find and access through websites or a downloaded file. However, some were only found through links within databases and many require users to register for a login, although at no cost. A major disadvantage was that some databases appeared to be outdated, and many of the databases were unavailable (as of December 2013).

3.1.2 Ease of Use

Many of the databases listed are structurally similar to EVRI and ENValue, containing search menus yielding bibliographies and necessary information for benefit transfers. Search menus are in the form of a matrix, pull-down menu, or manual text input. This allows for simple searches by keywords, geographical region, habitat type, ecosystem service, valuation method, or other variables. Other databases such as the National Ocean Economics Program (NOEP), allow for more advanced searches, and provide the additional use of an interactive Google map (Figure 1). This allows users to locate studies on a local, regional, and international level.

Some developers do not host searchable databases and present a cumulative, uncategorized reference list in a single file (i.e. Lincoln University). The disadvantage is that it becomes difficult for users to find specific types of information. The remaining databases consist of different types of resources related to the process of ecosystem service valuation (Table 3). One category of databases contains tools and software programs that can be downloaded in order to facilitate the valuation process. Some of these tools (i.e., SolVES) require specific software programs, such as Maxent maximum entropy modeling software or ArcGIS software with Spatial Analyst Extensions for working with grid-based data. Depending on the researcher's background and technological skills, these types of databases may vary in ease of use.

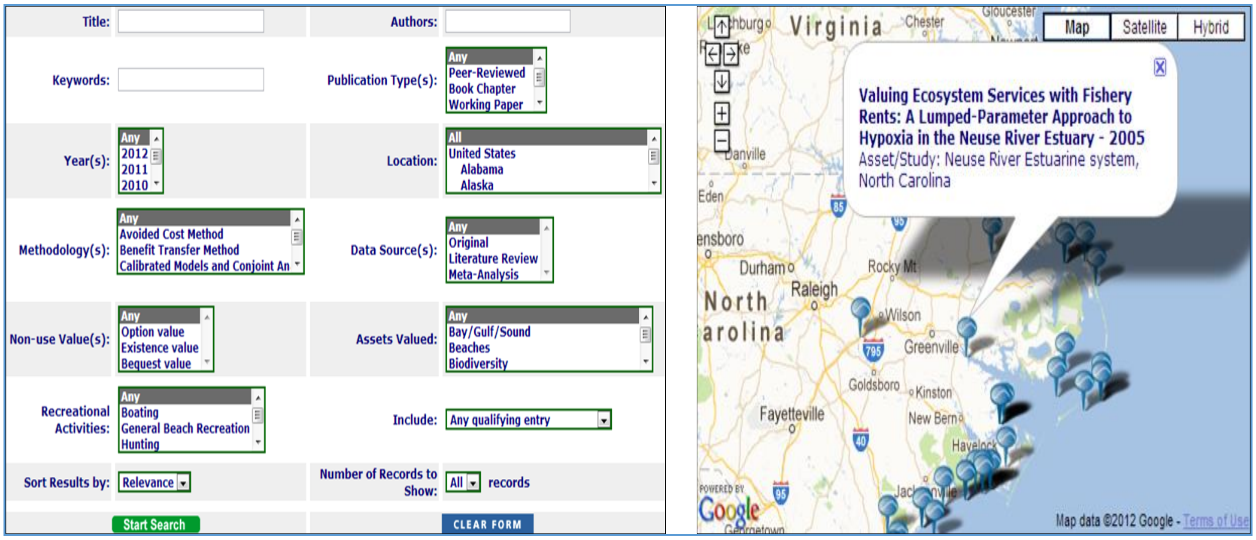


Figure 1: Examples of NOEP Search Menu and Map

3.1.3 Content

Overall, the databases provide search results consisting of benefit transfer requirements and corresponding references. These databases contain studies that used economic-based valuation methods. Most of the values provided in search results were provided for the purpose of benefit transfers and cost-benefit analyses (Table 4). For these purposes, results reveal the environmental attribute being measured, population description, location details, methods, comparable welfare measurement (units), and reference for validity (Villa et al., 2002).

Table 4: Example of Output Results for "Gas regulation in freshwater wetlands" in the GecoServ Database

Ecosystem	Service	Adjusted Values	Units	Country	States	Method [a]	Author
Freshwater Wetlands	Gas Regulation	$469.18	US$ 2008/per ha/per year	Europe	Danube Floodplains	BT, RC	Gren (2005)
Freshwater Wetlands	Gas Regulation	$68.83	US$ 2008/per household	USA	Florida	WTP	Shrestha & Alavalapati (2004)
Freshwater Wetlands	Gas Regulation	$54.30	US$ 2008/per ha/per year	China	Sanjiand Plain	PM	Tong et al. (2007)

Note: Since this is an example from the GecoServ database, we have not provided the citations in our list of references. However, the citations to these three studies can be found as http://www.gecoserv.org/ under the "References" tab.
[a] BT = Benefit transfer, RC = Replacement cost, WTP = Willingness to pay, and PM = Productivity methods. Further details on each can be found at http://www.gecoserv.org/ under the "Definitions" tab.

Bibliographies are useful in that they provide background information derived from published valuation studies. However, they do not include raw data, models or descriptions of how valuation methods were applied, or provide access to publications. For example, the majority of the values provided have been adjusted to the U.S. dollar but there is no information describing how this was done. It is important to understand how values were formulated so that they may be used as an accurate comparison. Moreover, the type of economic value is significant in that they could be “welfare-based or impact-based” (Villa et al., 2002). The lack of this information is one reason why other types of databases were included in this research. These databases consist of tools and software, social networks, ecosystem service indicators, and websites. Examples of some of the key databases are provided in Appendix B of this report.

While most databases provide general information on geographic location or habitat type, this information is minimal. Databases that simply report a location lack descriptions of the area. For example, additional information could describe if the study site was in a residential, industrial, or undeveloped zone. Location details are important because they allow researchers to further judge the relevance of study sites used for valuation.

3.1.4 General Comments

In general, the available databases are easy to access and allow for simple searches. With up to 2,000 studies, managers are able to identify studies related to various ecosystem services and geographic regions. However, the information is limited without access to publications. Although the EEPSEA database provides direct access to reference material, its geographic scope is of limited use to agencies and managers in the USA at this time. Most of the databases appear to be outdated while there is more attention on other types of valuation databases that include indicators, case studies, and valuation tools.

Since most of the databases were formed for the purpose of economic valuation, there is a large overlap among the types of studies, methods, ecosystem services, and geographical regions. This is evident among many databases and may partly explain the reason why some are unavailable or dormant. Rather than creating additional databases that overlap, existing valuation databases may need to consolidate or discontinue. Recognizing these issues, ecosystem service partners are beginning to merge, while others focus on developing different types of databases.

3.2 The Ecosystem Services Partnership

The ecosystem services approach became popular following the Millennium Ecosystem Assessment, directed by the United Nations Environmental Program (UNEP) in 2000 (MA, 2005). The vital role of ecosystems called for action to value and monitor trends in ecosystem services, in order to ensure they are adequately considered in decision-making processes. In response, “The Economics of Ecosystems and Biodiversity (TEEB)” was initiated by UNEP. As part of TEEB’s initiative, the Ecosystem Service Partnership (ESP) was formed for international collaboration, resulting in the creation of regional and national chapters (TEEB, 2011).

The U.S. chapter is the National ESP, led by multiple stakeholders such as the Nicholas Institute of Duke University, NOAA, US-EPA, USDA, and USGS. The ESP is further divided into “biome expert” and “thematic working” groups. Biome expert groups, such as the Marine ESP, focus on ecosystem services assessment of specific biomes (e.g. forests, grasslands, wetlands, etc.). Thematic working groups focus on valuation tools, modeling, indicators, and information exchange. Since December 2012, the Marine ESP has been further developed to include over 800 studies and over 2,000 marine ecosystem service values. The library does not provide complete reports due to copyright, but MESP developers are willing to send requested publications through email. The MESP also recently initiated a newsletter containing news and updates, links to selected papers and reports, upcoming meetings and events, and grant opportunities.

The ESP and TEEB have become the overarching working groups on ecosystem services. A primary goal is to develop and mainstream a single valuation database and toolkit. Following extensive research, it was found that some of the primary ecosystem service valuation databases identified during this project are linked due to TEEB initiatives and ecosystem services partnerships (Figure 2). These links help to explain reasons for inactive databases and content overlap. Through TEEB and the ESP, several of these inactive databases are consolidating into the Ecosystem Service Valuation Database (ESVD) and Earth Economics' Ecosystem Service Valuation Toolkit (EVT).

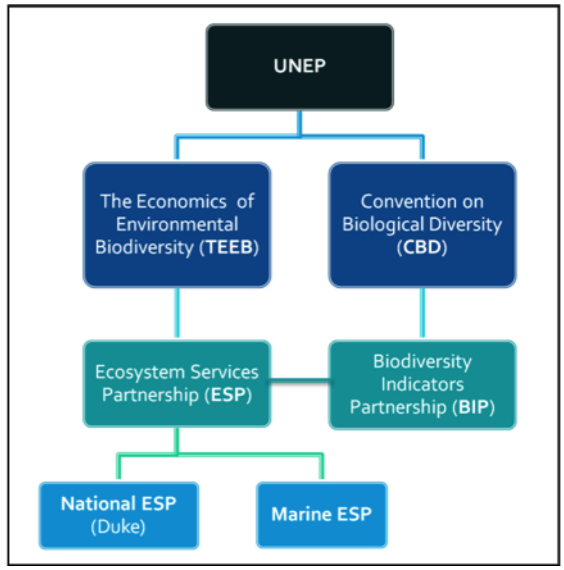


Figure 2: Hierarchy of Ecosystem Services Partnerships

The ESVD and EVT databases were originally scheduled for public release in December of 2012. Following an unexpected eight-month delay, the ESVD was made available for download through the ESP website in late-2013.[28] Limited access to the EVT database was made available through a new website developed by Earth Economics in August of 2013. Though a large amount of information is currently available for subscribed users, it is unknown when complete access to the database will be available.

3.3 The Importance of TEEB

The starting point for the development of the TEEB Ecosystem Services Valuation Database was the COPI Valuation Database, a result of the *Costs of Policy Inaction Report* and recommendations given in TEEB's *Scoping the Science Report* released in 2008 (Van der Ploeg & De Groot, 2010). The rationale for developing the database of value estimates was to inventory economic valuations of biodiversity and ecosystem services, and to provide an input to policy appraisal. Specifically, the database was set up so as to provide where possible not only a range of total values for a biome on a per hectare basis but also, where data are available, values disaggregated on the basis of ecosystem services (Table 5).

The TEEB Ecosystem Services Valuation database is a relational database developed in Microsoft Access. The main advantage of using a relational database is that selection of data can be done quickly and precisely on the basis of both the original data and linked to additional data (De Groot et al., 2010). Also, unit conversions can be changed easily and multiple classifications can be used without changing the underlying original data structure.

Other efforts were made by the Gund Institute-University of Vermont and Earth Economics to jointly develop the Ecosystem Services Database (ESD) and ARIES. However, the ESD did not reach its full potential within the grant period funded by the National Science Foundation. Earth Economics adopted the ESD in 2007 and built a new prototype that has grown exponentially in recent years as interest in ecosystem services

[28] http://www.fsd.nl/esp/80763/5/0/50.

valuation has grown. During this time, TEEB began to compile studies from existing databases (i.e. EVRI, ENValue, Nature Valuation, ESD, and ValueBaseSwe) to create a single standardized database known as the Ecosystem Services Valuation Database (ESVD). The ESD is now unavailable due to consolidation with the ESVD, and similar instances may be occurring in other inactive databases such as Nature Valuation. Since 2008, the ESP/TEEB has maintained the ESVD, which now contains over 1,350 monetary values from over 300 case studies. The ESVD is available for download as an Excel file, and will continue to be updated.

Table 5: Overview of the Main Data Types in the TEEB Valuation Database (TEEB, 2011)

Category	Data Element	Description
Identification within database	Unique ID number	Auto number: for identification of the estimate
Publication information	Reference	Both short and full citation
	Publication year	Year of publication of the article or report
	Publication type	Classification of different publication types
	Peer-reviewed publication	Yes/No
Location	Location name	Description of location of the case study
	Country	Selection from country/territory list
	Location coordinates	Location coordinates in WGS datum
	Scale of the case study	i.e. Local ecosystem/municipality, landscape, province, country, continent, world
	Protected status	Level of protection of the study area/landscape; three categories: unprotected, partially, completely protected of unknown
Ecological information	Biome/ecosystem type	Using the TEEB classification of different biome/ecosystem types
	Ecosystem	Using the TEEB subclassification of different ecosystems per biome
	Ecosystem services	Using the TEEB subclassification of ecosystem services
	Ecosystem service specification	Using the TEEB classification of ecosystem services
	Service area	Area (in hectares) for which the service value was estimated (as described in the publication)
Economic information	Valuation method used for the value	Using the TEEB classification of valuation methods
	Economic value	Value as presented in the publication
	Discount rate and years	Indicated when stock, PV, NPV and available in publication
	Unit	Unit used in the publication: e.g., AS$/ha, USD/yr or INR/ha/yr
	Currency	Currency used in the publication
	Year of value	Year of validation of value
Other	Used for TEEB?	Indication of the selection for the TEEB overview of estimates of monetary values of ecosystem services (De Groot et al., 2010)

Now that TEEB's Ecosystem Service Valuation Database is active, developers have indicated that the following updates will be done on a regular basis:

- Include original case studies and global estimates
- Provide monetary values of ecosystem services that can be attached to a specific biome and time period
- Provide information on surface area to which the ecosystem service value applies in order to make it possible to convert monetary values to US$/ha/yr
- Provide location descriptions, the service area, and the scale of research (local, region, country, and continent).

A large focus has been towards creating valuation tools, ecosystem benefits indicators, and social networks. In 2012, the ESP/TEEB collaborated with Earth Economics to develop an online portal called the Ecosystem Service Valuation Toolkit (EVT). This database provides a comprehensive set of resources for converting and analyzing ecosystem service values.

To access the database and tools, users must register and pay a fee for select features. The EVT offers:

- *SERVES*, a self-service tool for ecosystem service valuation and natural capital appraisal. This tool is fee-based and contains 450 search fields for a specific ecosystem service in a specific location.
- *Researcher's Library*, a community platform containing bibliographic information on over 45,000 published and gray literature ecosystem service valuation studies. Registered users may use the library to identify research gaps, to provide comments and reviews, and to connect with experts. Researchers are also able to assign a credibility ranking to both a study and a derived value.
- *The Repository*, a comprehensive database of published valuation data.
- *Resource Library*, containing materials for education, best practices, communication, and policy.

A primary contributor to the EVT is ARIES, a web-accessible application that builds and runs ad-hoc models of ecosystem services provision, use and spatial flow in a given area based on a user-dependent set of goals. The Gund Institute-University of Vermont (also developers of the former ESD) created ARIES to "help users discover, understand, and quantify environmental assets and the factors influencing values, for specific geographic areas and based on user needs and priorities." Other kinds of databases follow a framework based on ecosystem service indicators. These indicators are meant to quantify the capacity and actual delivery of ecosystem services, therefore providing links within the regulation and output of services. A separate branch of the ESP is the Biodiversity Indicators Partnership, initiated by the Convention on Biological Diversity. This partnership recently launched a database and network consisting of various chapters similar to the ESP.

3.4 Summary

The ECU project team was tasked with identifying and evaluating existing ecosystem service valuation databases. The initial review revealed that users are provided a vast resource of ecosystem services valuation studies conducted throughout the world. While most databases were created for the purpose of benefit transfer, search results provide limited information on the types of studies conducted, valuation methods, and ecosystem service values. Reference lists of up to 2,000 studies are provided but most do not include access to publications. Therefore, it becomes difficult to find pertinent information on geography, habitat type, and valuation methods used in studies. Another issue is that many databases are outdated and contain overlapping information, though many of these databases have consolidated. As social networks expand and technology advances, the amount of resources and state of knowledge are rapidly increasing. Therefore, a common ground for ecosystem service valuation research was needed.

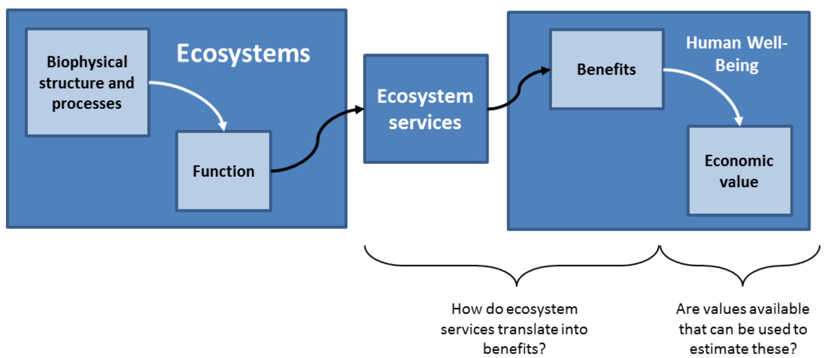
Many of the databases identified in the search are now part of TEEB and ESP goals. As TEEB continues to develop its database, the ESVD is of potential use to managers. However, Earth Economics' Ecosystem Services Valuation Toolkit will most likely become the primary resource for ecosystem services valuation. Based on review criteria and recent database activities, other potentially useful databases for coastal managers in particular are GecoServ, NOEP, and the Marine ESP. However, a variety of ecological, economic, social and political studies may still need to be considered. For instance, a wide range of studies related to ecosystem service valuation exists in the human dimensions literature. This type of research uses a theoretical framework to understand people's beliefs, perceptions, attitudes, and other types of concepts related to the way people value natural resources.

SECTION 4: ANALYSIS OF GAPS BETWEEN POLICY QUESTIONS AND AVAILABLE ECOSYSTEM SERVICE VALUE ESTIMATES

This section compares the policy questions we discuss in Section 2 to the available data on the economic values of ecosystem services (i.e., prior estimates) we reviewed in Section 3. In performing this gap analysis, we focus on estimates available from the TEEB Valuation Database (TEEB, 2011) and the GecoServ databases. The section begins by framing the valuation exercise that would need to be undertaken to address the policy questions. We then provide additional context on the two databases. Next, we assess the availability of estimates of the economic values of ecosystem services in the TEEB and GecoServ databases that could be used in valuation exercises and discuss the gaps that exist. Finally, we synthesize the results across the two databases.

4.1 Valuing Ecosystem Services to Answer Policy Questions

Figure 2 summarizes the pathway from ecosystem processes to economic value. The figure highlights where *existing* estimates of ecosystem service values fit into the flow of translating ecosystem services into human well-being. In short, ecosystem structures or processes (e.g., sand dunes, salt marshes) lead to some ecosystem function (e.g., a barrier, nesting/nursery habitat). This functionality provides a service (e.g., storm protection, fishery supply) which contributes to human well-being by providing a benefit (e.g., reduced damage to property, fish as food) which in turn has a value to society (e.g., the value of protected property, value of fish caught). This gap analysis is concerned primarily with the last part of that sequence: the values used to estimate economic benefits.



Adapted from Figure 1.4 of de Groot, Rudolf, Brendan Fisher, and Mike Christie, 2010. "Integrating the Ecological and Economic Dimensions in Biodiversity and Ecosystem Service Valuation," Chapter 1 in *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*, Pushpam Kumar, ed., Earthscan.

Figure 2 - Pathway from Ecosystem Structure and Processes to Economic Value

In performing this assessment, we are assuming that a *benefit transfer* would be used to estimate value of the services.[29] Benefit transfer is the process of taking values of ecosystem services estimated in certain geographic areas (study sites) and applying them to the area of interest (policy site) following some adjustments to ensure that they are relevant to the area where

Study site *– A site where value estimates have been developed through original research*
Policy site *– A site were value estimates are needed, but are not currently available.*

[29] Otherwise, a project could be designed to develop original estimates.

they are being applied. Benefit transfer approaches eliminate the need for developing a study to estimate values, but still require the need for economic expertise to ensure relevant study sites are selected and that the transfer is done correctly.

Benefit transfers can be performed in three general ways:

(1) *Using **point estimates** from similar sites for the same ecosystem services.* Under this approach, a researcher identifies a "study site" where estimates have been developed and applies those to the "policy site" where the estimate is needed. The key to this approach is to find a study site that is similar[30] to the policy site. It is also possible to identify two or more study sites and combine the point estimates in some way (e.g., average, weighting, etc.).

(2) *Using the **value function** from a study site.* Under this approach, the estimated functional relationship is used rather than the final point estimates. This can be done when (a) the functional relationship is provided for the study site and (b) enough information on the policy site is available to provide inputs into the value function.

(3) *Performing a **meta-analysis** based on values and information across multiple study sites.* Under this approach, estimates and information from multiple sites are used to develop an equation that relates various factors (independent variables reflecting demand and supply side factors) to estimated values (dependent variable) and then provides an estimate for the policy site.

Previous reviews and studies have found that the second and third tend to result in more valid and reliable estimates compared to the first (Rosenberger and Loomis, 2003; Shrestha and Loomis, 2001). Nevertheless, the first approach may be warranted and useful in some circumstances when comparable sites can be identified.

Using the economic values of ecosystem services in policy- or decision-making in a benefit transfer framework will require having estimates of values that are specific to both ecosystems and the specific services being provided. Thus, in assessing gaps the sufficiency of the current state of estimated values, we need to consider the number of estimates that are available for specific services within specific ecosystems. For example, we will need to know the number of specific estimated values for storm protection provided by salt marshes are available in order to determine the likelihood that a policy-maker will be able to identify relevant values for a benefit transfer. Ecosystem/ecosystem service combinations with a larger number of estimated values should, in theory, be more likely to result in successful benefit transfers. Ecosystem/ecosystem service combinations that have few values may not be able to support benefit transfers since relevant values may not be found for the policy-maker performing the benefits transfer.

4.2 Characteristics of Values Databases

4.2.1 TEEB

The TEEB database categorizes the ecosystem services using a four-tiered structure:

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[30] "Similarity" would need to account for both supply side (e.g., ecosystem characteristics) and demand side (e.g., income, preferences) conditions (Freeman, 2003; page 454).

Biomes → Ecosystems → Ecosystem Services → Ecosystem Subservices

A biome contains multiple ecosystems. The ecosystems provide service and those services can be more finely categorized into a set of subservices. Many of the biomes, however, are not relevant for assessing coastal and marine-related issues. Thus, we restricted our assessment to five biomes:[31]

- Coastal - this includes sea grass/algae beds, shelf sea, estuaries, and shores (beach and rocky)
- Coastal wetlands – this includes tidal marshes and mangroves
- Coral Reefs
- Inland Wetlands – this includes floodplains and peat wetlands
- Marine – this is open ocean

In selecting these five biomes, we chose to include inland wetlands as part of our assessment even though we are primarily concerned with coastal policies. There are two reasons for this. First, the TEEB documents make a distinction in the database itself between coastal and inland wetlands, but the TEEB documentation does not consistently separate the two. Second, we expect some of the studies may be applicable to coastal policy-makers if the inland wetland is close to a coastal area. We also chose to exclude the "lakes and rivers" biome since we expected it would be less relevant to coastal policy-makers. Table 6 contains a list of the ecosystems, ecosystem services, and ecosystem subservices in the TEEB database that fall under the five biomes we focus on.

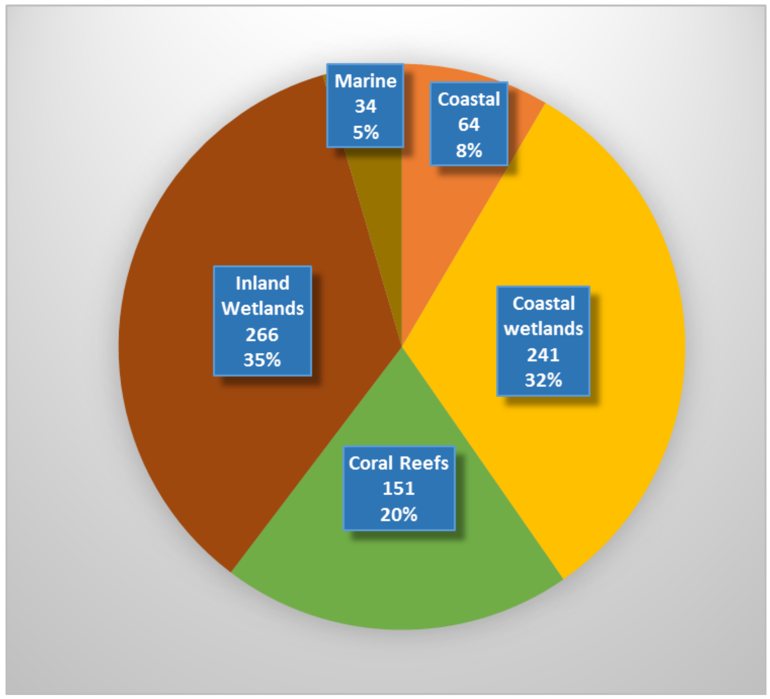

Figure 3: Distribution of Estimates across Biomes in TEEB Database

At the time we downloaded it (March 22, 2014), the database had a total of 1,310 economic value estimates in it, with 756 (58 percent) of those being in the five biomes we focus on. Figure 3 provides a distribution of the estimates across the five biomes.

[31] De Groot, et al., (2010) contains details on what constitutes these biomes and provides information on how TEEB defined the biomes.

Table 6 - Biomes, Ecosystems, Ecosystem Services, and Ecosystem Subservices in the TEEB Database Related to Coastal and Marine Issues

Category	Category Elements (within the coastal, marine, and water-related biomes)		
Biomes	• Coastal • Coastal wetlands • Coral Reefs • Inland Wetlands • Marine		
Ecosystems	• Coastal [unspecified] • Continental Shelf Sea • Coral reefs • Estuaries • Floodplains • Mangroves	• Marine [unspecified] • Open ocean • Peat wetlands • Riparian buffer • Salt water wetlands • Seagrass/algae beds	• Shores • Swamps / marshes • Tidal Marsh • Tropical forest general • Wetlands [unspecified]
Ecosystem Services	• Aesthetic • Air quality • BioControl • Climate • Cognitive • Cultural service [general] • Energy • Erosion • Extreme events • Food	• Genepool • Genetic • Inspiration • Medical • Nursery • Ornamental • Other • Pollination • Provisioning service [general] • Raw materials	• Recreation • Regulating service [general] • Soil fertility • Spiritual • TEV • Various • Waste • Water • Water flows
Ecosystem Subservices	• Animal genetic resources • Artistic inspiration • Attractive landscapes • Biochemicals • Biodiversity protection • Biological Control [unspecified] • Biomass fuels • Bioprospecting • C-sequestration • Capturing fine dust • Climate regulation [unspecified] • Cultural use • Cultural values [unspecified] • Decorations / Handicrafts • Deposition of nutrients • Disease control • Drainage • Drinking water • Dyes, oils, cosmeitcs (Natural raw mate • Ecotourism • Education • Energy other • Erosion prevention	• Fibers • Fish • Flood prevention • Fodder • Food [unspecified] • Fuel wood and charcoal • Gas regulation • Genetic resources [unspecified] • Hunting / fishing • Inspiration [unspecified] • Irrigation water [unnatural] • Maintenance of soil structure • Meat • NTFPs [food only!] • Natural irrigation • Nursery service • Nutrient cycling • Other • Other ESS • Other Raw • Pets and captive animanls • Plants / vegetable food • Pollination [unspecified] • Prevention of extreme events [unspecified]	• Provisioning values [unspecified] • Raw materials [unspecified] • Recreation • Regulating [unspecified] • River discharge • Sand, rock, gravel. Coral • Science / Research • Soil formation • Solar Energy • Spiritual / Religious use • Storm protection • TEV • Timber • Tourism • Various • Waste treatment [unspecified] • Water Other • Water [unspecified] • Water purification • Water regulation [unspecified

As can be seen in Table 6, there are numerous ecosystems, services, subservices used within the TEEB database. Figure 4 provides a distribution of the estimates by ecosystem. Of the 756 total estimates, almost 40 come from the top two ecosystems in the database (coral reefs and mangroves). Figure 5 provides a distribution of the estimates by ecosystem service. Among services, the top three services (food, recreation, and raw materials) account for 46 percent of all estimates.

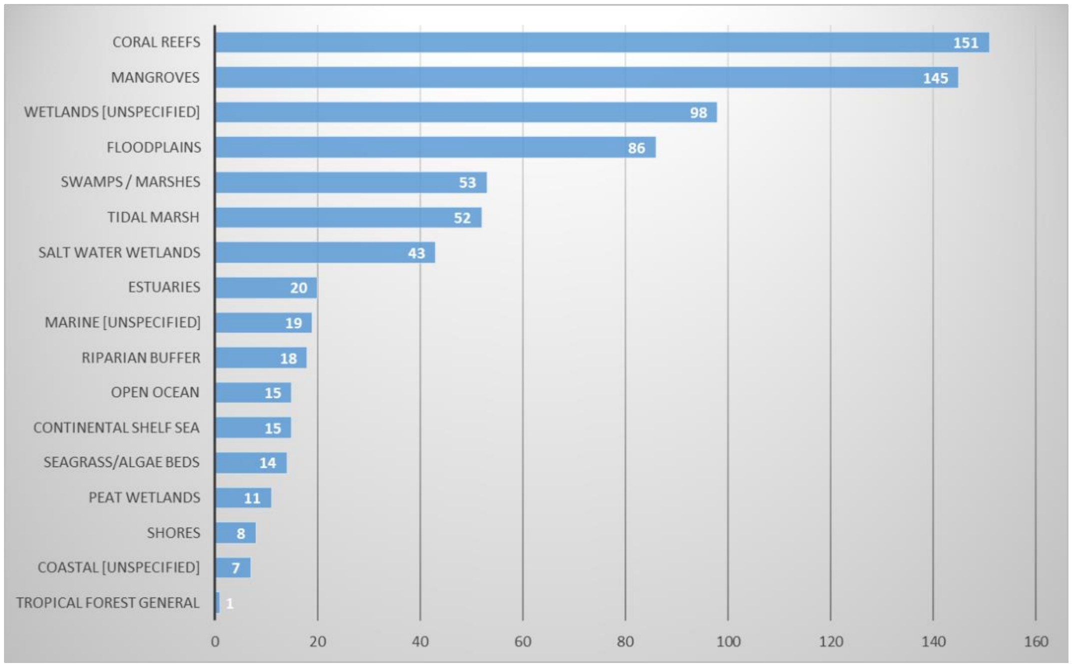

Figure 4: Distribution of Ecosystem Service Value Estimates by Ecosystem in TEEB Database

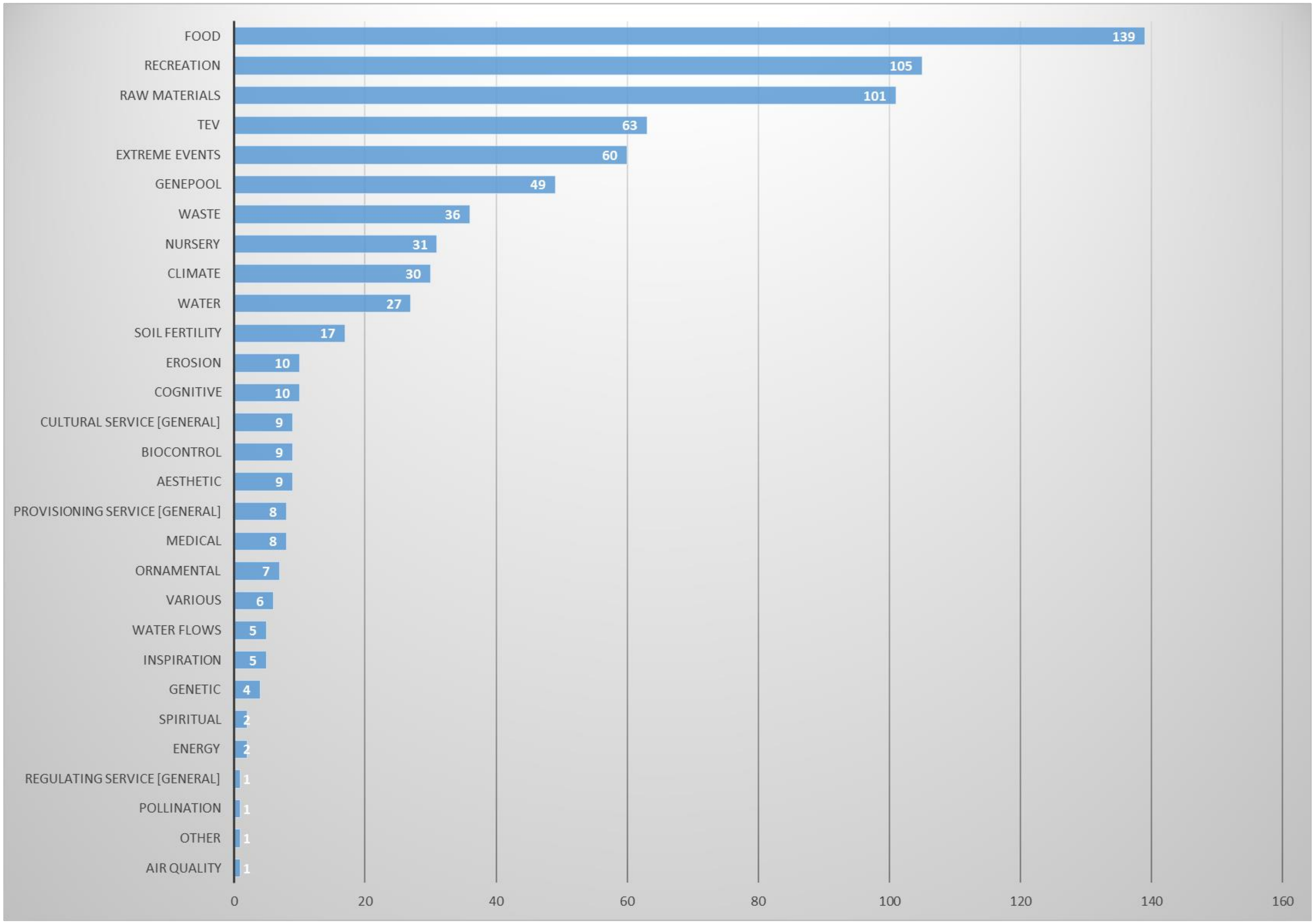

Figure 5: Distribution of Ecosystem Service Value Estimates by Ecosystem Service in TEEB Database

4.2.2 GecoServ

As opposed to the TEEB database, the GecoServ database focuses on coastal-related ecosystem services. The GecoServ database organizes the estimates by ecosystem type and service. The version of the database we analyzed included ten ecosystem types:[32]

- Freshwater wetlands
- Saltwater wetlands
- Coral reefs
- Mangroves
- Beaches
- Marine waters
- Seagrass
- Oyster reefs
- Dunes
- Systems
- Barrier islands

GecoServ defines "systems" as a set of interconnected ecosystems. The database documentation notes that there are three total studies that provide values for "systems" in the database and the three studies cover a bay, an estuary, and a system of mangroves and coral reefs. Figure 6 provides a distribution of the number of value estimates by ecosystem type in the GecoServ database. As with the TEEB database, the number of estimates is concentrated among a few ecosystem types with 45 percent coming from the top two (freshwater and saltwater wetlands) and 80 percent coming from the top four (freshwater wetlands, saltwater wetlands, coral reefs, and mangroves).

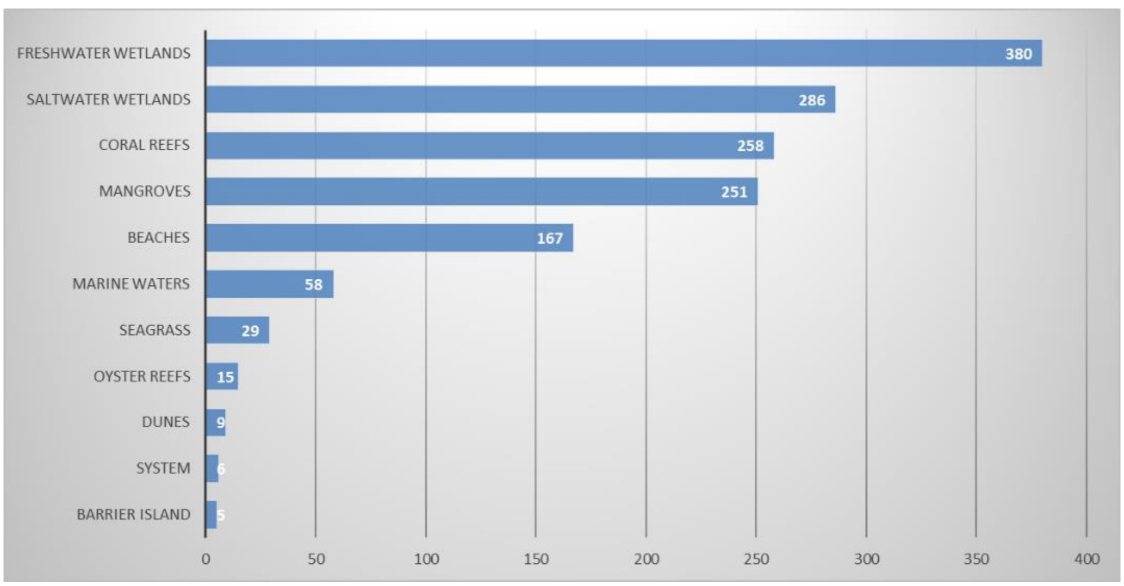

Figure 6: Distribution of Ecosystem Service Value Estimates by Ecosystem in GecoServ Database

[32] The GecoServ database is constantly being updated. ERG accessed information on the database contents on May 6, 2014. In compiling the information in this section, we used the "GecoServ Statistics" file found at http://gecoserv.tamucc.edu:81/gecoserv/resources/Statistics.pdf on May 6, 2014.

Figure 7 provides a distribution of the estimates in GecoServ by ecosystem services. Once again, there is a heavy concentration among a few services. Nearly one-third of the estimates are associated with recreation and 63 percent are associated with the top 4 (recreation, disturbance regulation, habitat, and food).

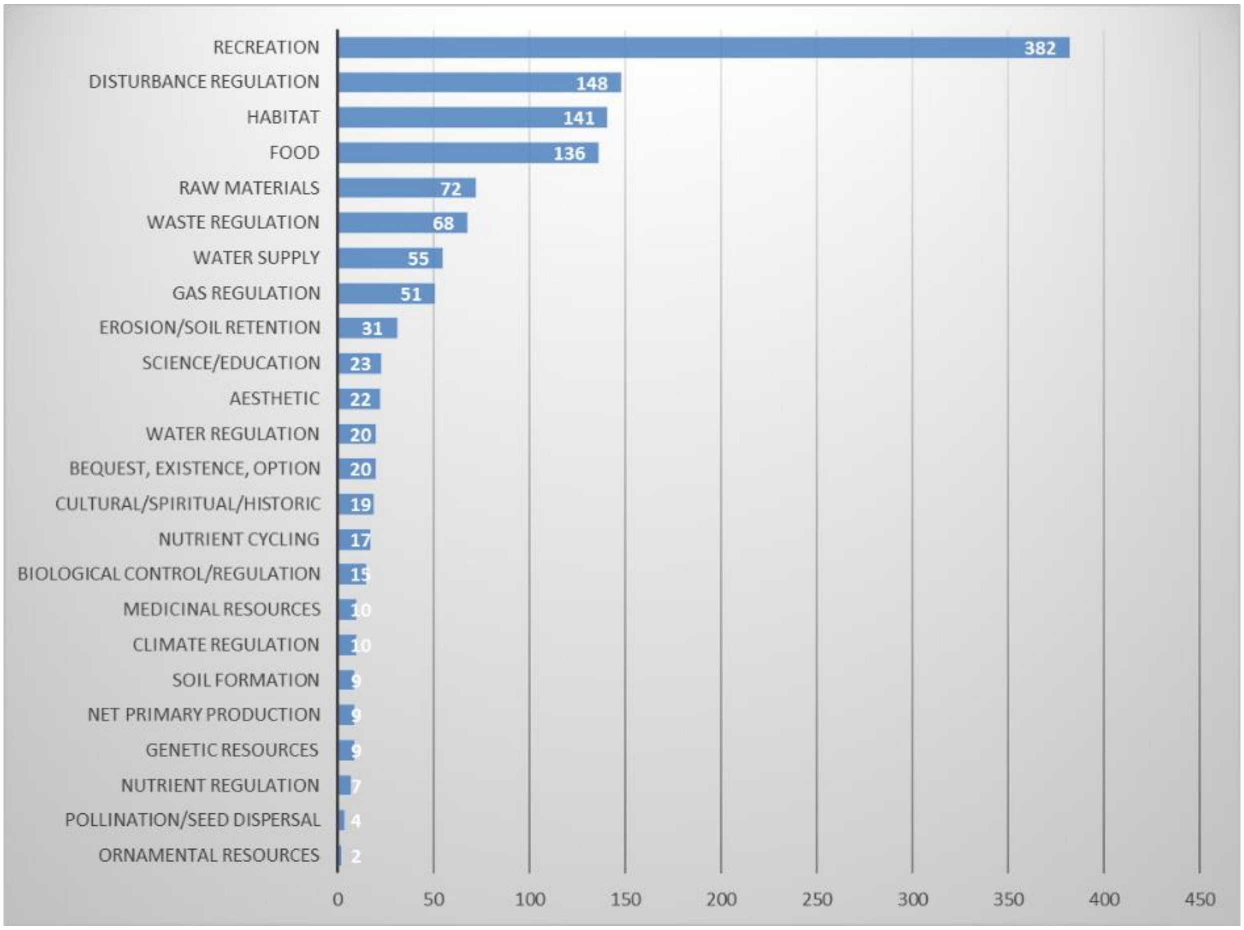

Figure 7: Distribution of Ecosystem Service Value Estimates by Ecosystem Service in GecoServ Database

4.3 Gap Analysis

ERG analyzed the number of value estimates in the TEEB and the GecoServ databases by cross-tabulating ecosystems and ecosystem services. In assessing gaps, we use a color coding scheme to depict the availability of estimates:

- No estimates: dark red
- From 1 and 3 estimates: red
- From 4 and 9 estimates: orange
- From 10 to 19 estimates: yellow

- From 20 to 39 estimates: light green
- 40 or more estimates: Green

The purpose of the color-coding is to depict potential gaps (and areas of sufficient estimates). Shades of red indicate significant potential gaps while shades of green indicate areas where researchers are *more likely* to find relevant estimates to use in a benefit transfer. The ranges we have selected and the associated colors are based on ERG's best professional judgment. We note, however, that the first "green" category (20-39 estimates, light green) corresponds to at least 20 estimates, a relatively large number of estimates given the databases we reviewed. Additionally, the orange and below categories all correspond to less than 10 estimates, which should be considered very small values. We have based this gap analysis solely on number of estimates available; the premise being that the larger number of estimates available, the more likely it will be to find suitable study sites for a benefit transfer. Also, we refer to these as "potential gaps" since the two databases may not contain all relevant estimates.

We also provide separate gaps matrices for each database. There are two reasons for this approach. First, there are several studies that are in both databases. Thus, ERG would have needed to review each study entry in each database to determine if it was included in the other database. Second, the two database use different classification schemes. Although similar, there are some differences that ERG would have needed to reconcile.

The different general questions require different levels of gap assessment. The first general policy question (the extent to which ecosystem service values can be used to inform stakeholder and support policy directions) requires assessment of gaps at the ecosystem level. In general, policy-makers using ecosystem service values for this purpose require more general information. They are not trying to assess a specific trade-off, but are providing information to stakeholders to indicate potential values of some services within a specific ecosystem. On the other hand, policy-makers using the economic values of ecosystem services to address the second and third general questions need values that can be applied (through benefits transfer) to their specific situation. Thus, for the second and third general questions, more detailed information on the values is required. In assessing gaps for the first general question, we will look at gaps at the ecosystem level; that is, do the ecosystems covered in each database provide sufficient estimates to provide information to policy-makers' stakeholders? For the second and third general question, we will assess gaps at the ecosystem service level within ecosystems; that is, we need to know whether specific services within specific ecosystems are covered by estimated monetary values.

Finally, before presenting the gaps matrices for each database, we note that the gaps we are identifying are not reflective of the quality of the two database projects. Both the TEEB database and GecoServ database provide a substantial number of estimates and ultimately the databases reflect the best available information on the economic values of ecosystem services that have been estimated. The gaps we identify reflect gaps in the current set of information in relation to the general questions we are posing. The databases provide a useful means of assessing the quantity of that information.

4.3.1 Gaps Matrix for TEEB Database

Figure 8 provides the gaps matrix for based on cross-tabulating ecosystems and ecosystem services for the five selected biomes using the color scheme from above. At first glance, there are clearly numerous gaps in the cross-tabulation. However, some of the “gaps” are for combinations that are irrelevant. For example, that there are no pollination-related values for the open ocean ecosystem should be of little concern. On the other hand, there are only two estimates for the nursery-related values of estuaries. ERG has not performed an assessment of whether the combination of an ecosystem and a service is relevant.

Ecosystem-level gaps

The TEEB database covers its in-scope ecosystems fairly well within the five biomes it uses to define its database. Only one ecosystem (tropical forests) has a small number of estimates. Most of the ecosystems are assessed in the yellow (10 – 19 estimates) to green (40 or more estimates) range. Based on this, we can conclude that using ecosystem service values for providing information to stakeholders (i.e., general question #1) can be done reasonably well using the TEEB database. For each ecosystem, there appear to be a number of estimates that can be used for informational purposes.

Service-level gaps

At the service level within specific ecosystems there are several gaps. As noted, many of the ecosystem services without any estimates may not be relevant services for the specific ecosystem (e.g., pollination in the open ocean). However, there are few services that are assessed in the yellow to green level. The only ecosystems that have services in the light green or green level are coral reefs and mangroves. Thus, based on this, we can conclude that there are significant gaps in the current state of information in the TEEB database to answer the second and third general questions on assessing specific trade-offs.

		Ecosystems																
Ecosystem Services	Total	Coastal [unspecified]	Continental Shelf Sea	Coral reefs	Estuaries	Floodplains	Mangroves	Marine [unspecified]	Open ocean	Peat wetlands	Riparian buffer	Salt water wetlands	Seagrass/algae beds	Shores	Swamps / marshes	Tidal Marsh	Tropical forest general	Wetlands [unspecified]
Aesthetic	9			4					2						3			
Air quality	1						1											
BioControl	9	1	2	1		1			2		1		1					
Climate	30			4		4	6	2	2	2	1	2	1		2	2		2
Cognitive	10			9	1													
Cultural	9							2			2	2		1	1			1
Energy	2			1									1					
Erosion	10	1		2		1	3				1	1						1
Extreme events	60			15	1	3	10	1		3	1	5		1	6	10		4
Food	139	3	4	29	8	19	29	5	2			2	3	1	9	9		16
Genepool	49	2		10		5	7	1	1	1	2	4			5	1		10
Genetic	4			2		1						1						
Inspiration	5			3		1									1			
Medical	8					3	3											2
Nursery	31			1	2		17			1		4	1		1	2		2
Ornamental	7			6											1			
Other	1																	1
Pollination	1					1												
Provisioning	8			1		1	2				1	1	1		1			
Raw materials	101			7	3	17	41	1	1			3	1		6	3		18
Recreation	105		3	39	1	8	6	4	2	1	3	6		3	2	12	1	14
Regulating	1											1						
Soil fertility	17		2	1	1	3	1	2	2			2	1		1			1
Spiritual	2			1	1													
TEV	63		3	13	2	3	13	1	1	1	3	4	3	1	3	6		6
Various	6					1	2					1		1				1
Waste	36			2		7	2			2		3	1		5	5		9
Water	27		1			5	2				3	1			4	2		9
Water flows	5					2									2			1
Total	**756**	**7**	**15**	**151**	**20**	**86**	**145**	**19**	**15**	**11**	**18**	**43**	**14**	**8**	**53**	**52**	**1**	**98**

Figure 8: Gaps Matrix for TEEB Database: Ecosystems and Ecosystem Services for Coastal, Coastal Wetlands, Coral Reefs, Inland Wetlands, and Marine Biomes

4.3.2 *Gaps Matrix for GecoServ Database*

Figure 9 provides the gaps matrix for the GecoServ database. The GecoServ database includes fewer services, fewer ecosystems, and a larger number of total studies which means that there is a larger percentage of services within ecosystems that are assessed in the light green to green range. However, there are also significant numbers of cells in the figure with few to no estimated values. In cases where there are no or few estimates, it may also not be possible to conclude there is a significant gap: the service may be irrelevant or relatively unimportant for the ecosystem. To adjust for this, we used Barbier et al.'s (2011) assessment of the ecosystem service values values for coastal and estuarine ecosystem services which identified the relevant services for coral reefs, salt marshes, mangroves, seagrass, and beaches and dunes.[33] When Barbier et al. (2011) identified a service as being relevant for an ecosystem we depicted that using a dark border around the cell.

Ecosystem-level gaps

Most of the ecosystems in the GecoServ database have sufficient numbers of estimated values to support providing information to stakeholders. However, oyster reefs, dunes, and barrier islands have few estimates to work with. Policy-makers needing information on freshwater wetlands, saltwater wetlands, mangroves, or coral reefs would be well-served by the GecoServ database. The same is true for policy-makers primarily interested in recreation on beaches; 80 percent of the estimates for beaches are associated with recreation. Thus, overall, the conclusion is mixed; for some ecosystems coverage is good while for others there are gaps.

Service-level gaps

At the service with each ecosystem level, we see that services within freshwater wetlands are well represented within the database. To a lesser degree, services within saltwater wetlands, mangroves, and coral reefs all have many services that are well-covered by estimates. Also, as mentioned above, recreation is the only service for beaches that is well-represented by ecosystem service value estimates. Services within the other ecosystems all show significant gaps for having estimates. Even when we apply the "relevancy adjustment" using Barbier et al. (2011), we still see significant gaps, especially for beaches, dunes, and seagrasses.[34] Thus, overall the conclusion is once again mixed with some ecosystems having good coverage in terms of ecosystem service value estimates and others with significant gaps.

[33] We attempted to do the same for the TEEB database, but found the taxonomy used by Barbier et al. (2011) to be more compatible with the GecoServ database and less compatible with the TEEB taxonomy.

[34] However, it could be argued that beaches and dunes could be combined and that the major services from beaches and dunes are recreation and disturbance regulation, both of which are well represented. However, beaches and dunes are also a significant habitat source which not well represented.

Category and Service	Total [a]	Freshwater Wetlands	Saltwater Wetlands	Mangroves	Coral Reefs	Beaches	Seagrass	Marine Waters	Oyster Reefs	Dunes	Barrier Island	System
Provisioning												
Water Supply	55	43	14	1		1		5				
Food	136	32	21	46	28	1	6	8	1			1
Raw Materials	72	33	15	43	6		3	3				
Genetic Resources	9	4	4		2							
Medicinal Resources	10	5		3	2							
Ornamental Resources	2	1			1							
Regulating												
Gas Regulation	51	25	11	19	2	1	2	5				
Climate Regulation	10	11	2	1	1			3				
Disturbance Regulation	148	39	53	31	27	11				4	1	2
Biological Control/Regulation	15	4	3	3	31		1	2				
Water Regulation	20	19	4	1								
Waste Regulation	68	36	25	8	5		1	2	1			
Soil Formation	9	5	2	1								
Erosion/Soil Retention	31	9	2	14	4	3			1			
Nutrient Regulation	7	5	3	2					2			
Supportive												
Nutrient Cycling	17	6	6	2	1		3	3	2			
Net Primary Production	9	4	6					3				
Pollination/Seed Dispersal	4	3	2									
Habitat	141	38	39	43	23	2	8	1	2			
Cultural												
Recreation	382	69	62	24	118	134		15	7	4	2	2
Aesthetic	22	23	10		11	5		2				
Science/Education	23	2	1	4	17		2					
Cultural/Spiritual/Historic	19	7	10		4	5		1		1		
Non-Use Values												
Bequest, existence, option	20	3	3	11	1	2		2			3	
Total for each Ecosystem [a]		**380**	**286**	**251**	**258**	**167**	**29**	**58**	**15**	**9**	5	6

[a] Total will not add to the sums of the rows/columns since some estimates cover more than one service and/or ecosystem.

Figure 9: Gaps Matrix for GecoServ Database

4.4 Synthesis across Databases

Looking at the two databases separately, however, does not provide a complete assessment of gaps. This section provides a synthesis of what TEEB and GecoServ databases can provide to answer the three general policy questions. To perform this synthesis, we cross-walked categories from the TEEB database into those for the GecoServ database. The results of this appear in the first two columns of Table 7. The cross-walk was from GecoServ to TEEB was straightforward for mangroves, coral reefs, seagrass and relatively straightforward for beaches and dunes (mapped to “shores” in TEEB) and marine waters (mapped to three TEEB categories). We combined the freshwater and saltwater wetlands categories in GecoServ and mapped that to several categories in TEEB to form a general “wetlands” category.

The first policy question (using ecosystem service values to provide information to stakeholders) requires information at the ecosystem level. There are three types of ecosystems where sufficient information appears to exist that could be used for providing information to stakeholders:

- Wetlands – Comparing the two databases, we see that the general “wetlands” category has a large amount of information. This is also true when viewed from the specific categories that comprise the general category such as estuaries, tidal marches, etc.
- Mangroves – Both databases contain sufficient estimates for providing information on mangroves.
- Coral reefs – Both databases contain sufficient estimates for providing information on coral reefs.

Additionally, beaches contain sufficient information if the primary purpose of providing the information is to provide recreation-related values. The other ecosystem categories on the other hand have few estimates for policy-makers to draw from. Although some of those estimates could be used to provide information, the relevancy of the values used could be questionable.

Table 7 also provides an assessment of the potential for meaningful benefits transfer to address the trade-off questions (policy questions 2 and 3) for each ecosystem type. In summary, we find that only mangroves, corals reefs, and recreation-related benefits of beaches have a high potential for a meaningful benefits transfer based on the available estimates. This does not, however, mean that a specific situation cannot be addressed by the available ecosystem service values estiamtes. It is always possible for a policy-maker and a trained economist, to identify one or several relevant studies for a specific situation from these two databases and to use those in a benefits transfer, even in cases where we indicate “low potential.” Each situation still needs to be addressed on a case-by-case basis.

Table 7: Cross-Walk between TEEB and GecoServ Ecosystem Categories and Assessment of Gaps for Performing Benefits Transfers

GecoServ Categories [a]	TEEB Cross-Walked Categories [b]	Overall Assessment of Gaps for Performing Benefit Transfers to Address General Questions 2 and 3
Freshwater and saltwater wetlands	Estuaries Floodplains Peat wetlands Riparian buffer Saltwater wetlands Swamps/marshes Tidal marsh Wetlands [unspecified]	The overall wetlands category has significant coverage of ecosystem service values through the GecoServ database. TEEB, however, disaggregates wetlands into multiple types in its taxonomy. When viewed from the TEEB taxonomy, there appear to be a number of gaps in assessing wetlands. For example, both estuaries and tidal marshes have a number of gaps in the TEEB matrix (Figure 8). We expect this to be an important distinction for wetlands since policy-makers would need ESVs that are specific to the type of wetland that they are valuing for general questions 2 and 3. Overall, we expect the potential for meaningful benefits transfers for wetlands to be low.
Mangroves	Mangroves	Mangroves are well-represented in the two databases. However, most of the estimates reflect non-U.S. sites since mangroves are less common in the United States. Nevertheless, the potential for performing a meaningful benefits transfer for mangroves is high.
Coral reefs	Coral reefs	Coral reefs are well-represented in the two databases with few gaps. The potential for performing a meaningful benefits transfer is high for coral reefs.
Beaches/dunes	Shores	There are significant gaps for valuing trade-offs related to beaches, dunes, and shores in general, except where policy-makers are interested in valuing recreation benefits. The potential for meaningful benefits transfers for beaches/shorelines is low, except for valuing recreation.
Seagrass	Seagrasses/algae beds	Both databases show significant gaps for valuing trade-offs for seagrasses and/or algae beds. The potential for meaningful benefit transfers is low.
Marine waters	Continental shelf area Marine [unspecified] Open ocean	Both databases contain significant gaps for these ocean/marine-related ecosystems. We expect the potential for meaningful benefit transfer to be low.
Oyster reefs	NA	Oyster reefs are only included in the GecoServ database and contains significant gaps. We expect to potential for meaningful benefit transfers in this case is low.
Barrier islands	NA	Barrier islands are only included in the GecoServ database and contains significant gaps. However, some studies included in the TEEB database may deal with barrier islands, but the database does not specifically call them out. If so, we would expect those studies to be in the “shores” category which also has significant gaps. We expect to potential for meaningful benefit transfers in this case is low.

[a] We excluded GecoServ category “Systems” from the cross-walk since it covered multiple ecosystems.
[b] Two TEEB categories were excluded from the cross-walk. We excluded “Coastal [unspecified]” from the cross-walk exercise since it was too general and we excluded “Tropical forest, general” from the cross-walk since it did not have a reasonable match in the GecoServ database and it had only one estimated value.

SECTION 5: USING ECOSYSTEM SERVICE VALUES IN POLICY-MAKING: MANAGED RETREAT AND INFRASTRUCTURE ADAPTATION PLANNING

This section presents two areas where ecosystem service values can be used in policy and decision-making: managed retreat and adaptation planning. The two are only examples and are not meant to reflect the importance of these issues or a particular need. The purpose of these two examples is to show how estaimted monetary values pf ecosystem service values could be used in general terms and to assess the extent to which ecosystem service value-related information is available to assist policy-makers in making decisions.

5.1 Managed Retreat

Managed retreat can be defined as allowing an eroding shoreline to advance inward and, in response, either demolishing or moving buildings back away from the encroaching shoreline. An alternative to managed retreat would be to build structures such as seawalls or dunes to protect property or to renourish eroding beaches to replace the lost sediment.

Ecosystem service values can be used to assess the economic viability of managed retreat approaches such as the one at Pacifica State Beach. Consider a situation similar to the one at Pacifica State Beach where a community must decide on whether to continue to armor a coastline to protect private property (residential and/or commercial) or follow a managed retreat approach. For this example, we can assume that armoring has been the current approach and so some level of armoring exists, but has proven somewhat ineffective at protecting the private property. We also assume that the primary concern is the potential damages from future storms. The analysis would involve comparing the cost and benefits of the two approaches to determine the best path, taking into account the values of ecosystem services.

This type of question falls under second general question we posed in Section 2. The option of armoring a shoreline could be thought of as a development option and managed retreat provides additional ecosystem services. Thus, the example involves a trade-off between development and ecosystem services.

5.1.1 Costs and Benefits

We can begin with the armoring approach and we summarize the costs and benefits in Table 8. First, the community would incur cost to build the structures to armor the shoreline. Second, some amount of maintenance cost would be incurred over time for the armoring structures. Thus, the first two costs are the standard capital and operations/maintenance costs that define any capital investment project. The timing of these costs would need to be accounted for and either an annualized value should be calculated or the total discounted value should be calculated. Building an armoring structure may result in the loss of some ecosystem services. For example, a sea wall may have impacts on beach recreation (as the beach in front of the sea wall erodes quicker than without the sea wall), habitat, aesthetics, and on spriritual comfort. This is where the first use of ecosystem service values comes in; we can use economic values to place a value on the project loss in ecosystem services from the current baseline due to building the armored structure. The benefits of the armoring approach involve the value of properties that are protected from damage; however, we would need to account for the probability that the armored structure would not protect the properties. The probability of the armoring not protecting the properties would involve modeling the effects of different storm types (e.g., 10-year storms, 50-year storms, etc.) and assumed sea-level rise scenarios on the shoreline to determine when the armoring would “fail” and to what degree.

Table 8 also provides the costs and benefits of the managed retreat option. The managed retreat approach would involve the cost of physically retreating from the shoreline. This could involve either purchasing the properties that are considered at risk or to physically move those properties back from the shore. Additionally, in this example we have assumed that some armoring currently exists; the shoreline retreat would also involve removal of this existing armoring. Finally, the property owners that are “moved back” will incur a loss associated with no longer being close to the ocean. For some, this involves the value that property owners place on being close to the ocean. For others, such as businesses that rely on location, the cost may involve lost income.[35] This loss to property owners can be considered an ecosystem service value; specifically, the ecosystem (beach/coast) provides either a psychic value to the property owner or to a business’ patrons. On the benefit side, retreating from the shoreline will result in protected properties; however, as with the armoring option, the analysis would also need to account for the probability that some storms would result in property damage. The area that the community retreats from can now provide increased levels of ecosystem services. For example, the retreat area can be converted to beaches (tourism and other recreation) and/or wetlands (habitat). The values of the projected increased ecosystem services should then be added to the analysis.

Table 8: Costs and Benefits of Armored Shore Protection and Managed Retreat in a Hypothetical Example

Approach	Costs	Benefits
Armoring	• Capital cost to build new armoring structures such as sea walls, etc. • Maintenance costs for the armoring structures • *Loss of ecosystem services (beach recreation, habitat, aesthetics, spiritual) from the current baseline level*	• The value of protected property, adjusted for the probability that some storms would still result in damage
Managed retreat	• Cost to move homes or, alternatively, to purchase the property from property owners and remove the properties • Cost to remove current armoring structures • *“Loss” to property owners who are now moved back from the ocean*	• The value of property that is moved back being protected from damage, adjusted for the probability that some storms would still result in damage • *Increased ecosystem services from the current baseline level*

Note: all costs and benefits would need to be appropriately discounted based on the time frame over which they can be expected to occur.

There are two levels of analysis that can be done to assess which option to select. First, the community could consider the changes in risk between the two options relative to the cost of each option. This analysis would involve comparing the expenses (cost of capital and maintenance cost for the armoring option and the cost to move/acquire the at-risk properties for the managed retreat option) to the change in risk to the properties associated with each option.

[35] For example, a restaurant that relied on its view of the ocean from its deck may see reduced patronage once the business is located further form the shoreline.

The second, more comprehensive analysis, would add in ecosystem service values. This more comprehensive analysis would need to account for the timing of the benefits. In each case, the benefits are accruing to the community in the future. If the benefits accrue to the community over different intervals, discounting will be important. For example, the benefits of armoring may be larger per year (compared to managed retreat) but accrue over a shorter time frame, while the benefits of managed retreat may be smaller per year (compared to armoring) but persist over a longer term. Appropriate discounting will allow for a valid comparison.

5.1.2 Availability of Values from TEEB and GecoServ Databases

We are assuming that estimating the value of the ecosystem services associated with the managed retreat example would involve using a benefit transfer approach. As discussed above, a number of ecosystem services would be affected by a managed retreat approach. First, a managed retreat approach will lead to increased wetlands as structures are removed and natural processes take over. Second, a managed retreat approach will lead to loss of aesthetic value to property owners and businesses as they are moved from the shoreline. Finally, beaches would be impacted as erosion takes sand from the beach.[36]

What ecosystem service value information is available for policy-makers to use in assessing managed retreat strategies? Beginning with wetlands, the GecoServ database appears to contain a fair amount of information on:

- Food,
- Disturbance regulation,
- Waste regulation,
- Habitat, and
- Recreation

Assuming that food is less of a concern for a managed retreat strategy, policy-makers, using the services of a trained economist, could search for relevant values to use to estimate the value associated with the other four services.[37] These values could provide a sense of what will likely be gained with a retreat approach or lost with additional armoring.

There are few studies, however, to assist the policy-makers in assessing the aesthetic losses associated with moving people and businesses from the shore. The Gecoserv database contains 10 estimates for salt water wetlands and TEEB has only three for swamps/marshes. Thus, the available information may not available for assessing aesthetic losses.

[36] It is also possible to create a scenario where beaches are enhanced by retreat; for example, if the retreat involves removal of a sea wall that had inhibited beach formation.

[37] Although disturbance regulation is one area covered by ESVs for saltwater wetlands, policy-makers may want to use site-specific hydrologic modeling to better approximate benefits associated with storm impact reduction.

5.2 Adaption Planning

In June 2013, NOAA released guidance for communities to use in sea level rise adaption planning entitled *What Will Adaptation Cost? An Economic Framework for Coastal Community Infrastructure*.[38] The guidance focuses on the step communities can take to assess adaption options. The primary costs and benefits discussed in the document deal with the cost and benefits of protecting structure from flooding associated with sea level rise. The document, however, also list impacts on ecosystem services associated with adaptation, including:

- Improved recreation opportunities
- Increased property values associated with being in better protected community
- Enhanced ability to attract new business
- Improved quality of life (decreased anxiety, increased safety)
- Enhanced aesthetics

The guide itself is designed to compare adaption scenarios developed by the community planners/decision-makers with a "no action" scenario. The guide also encourages the consideration of more than one adaption scenario and provides a number of potential options in its Appendix A. With this in mind, one can envision a community considering two adaption strategies against a "no action" scenario to determine the best course of action. For sake of argument, we can assume that the two adaption strategies are polar opposites: the first would rely in hard structures such as dikes, levees, and seawalls to protect the community while the second would rely on preservation of open space and restoring/building wetlands to accommodate flood waters.

The guide provides a four-step process that policy-makers can work through to get to a decision. In what follows, we walk through the four-step process for the constructed example from above, highlighting where ESVs would provide useful information into the process beyond the cost and benefits associated with buildings and infrastructure.

- **Step 1 – Understand baseline risk.** In the first step, the planners would develop sea level rise scenarios and high water-level events (e.g., 10-year storms, etc.) specific to the area under consideration. This information would be used to assess the structures and infrastructure is at risk from sea level rise-related flooding.
- **Step 2 – Assess what can be done differently.** The second step is where the planners develop adaption strategies. For our purposes, we have assumed that two would be developed: one that relies on engineered structures and one that relies on natural solutions. Once the specifics of these are defined, the risk to buildings and structures is re-assessed; specifically, how well does each scenario perform in protecting the built infrastructure.

[38] http://www.csc.noaa.gov/digitalcoast/publications/adaptation.

- **Step 3 – Calculate the costs and benefits.** In the third step, costs and benefits are calculated. The first set of benefits for each scenario will relate to the reduced impacts on buildings and structures. However, a second set of benefits will include ecosystem services. For example, adding wetland could provide habitat for wildlife and additional/other recreational values. Thus, access to reliable ecosystem service value estimates would allow planners to better anticipate benefits from adaption strategies. Costs are also calculated in step 3. Generally, these refer to the costs associated with implementing the strategy (e.g., construction and operations/maintenance costs). However, loss of ecosystem services can also play a role in cost calculations. For example, building sea walls may lead to lost ecosystem functioning. Thus, in Step 3 of this process, ecosystem service values would provide valuable input.
- **Step 4 – Make a decision.** In the final step of this process, the guide discusses how to assess the information developed under the first three steps to make a decision. Certainly, comparison of costs and benefits plays a central role in this process. This is where adding in ecosystem service values to our example would have the most value. As noted in Step 3, adding in ecosystem service considerations would lead to a higher estimate for the benefits of the "natural" scenario (i.e., increasing wetlands and relying on open space) and a higher estimate of the cost associated with "engineered structures" adaptation scenario (i.e., sea walls, dikes, and levies). Thus, without taking into account ecosystem service impacts, planners would be biased toward the "engineered structures" approach relative to the "natural" one.

SECTION 6: SUMMARY AND OBSERVATIONS

This section presents our summary of findings from the research done under this project and also provides additional observations that stem from the research we performed.

6.1 Summary of Key Findings

There is ample opportunity to apply ESVs in policy- and decision-making.

Our review of policies in three states, discussions with those three states, and discussions with additional states at the 2013 NOAA state managers meeting has shown us that there is ample opportunity to apply the economic values of ecosystem services in policy- and decision-making at the state level. Our limited review found many cases where state laws appear to set priority use of land or coastal areas. For example, Massachusetts is clear that natural systems are a priority over engineered structures in terms for storm protection. North Carolina also is clear that conservation measures should be preferred to development in areas of environmental concern (AECs) and that certain types of development are explicitly prohibited in AECs. These state-level policies clearly provide the scope for considering the value of ecosystem services and it could be argued even call for consideration of the value of ecosystems. Furthermore, our discussions with the state policy-makers found that ESVs are not used in decision-making, but there is a need for their consideration.

Although we only reviewed documents from three states, we expect that many other states have the same types of opportunities. Specifically, legislation or policies that call for “balancing” or “assessing trade-offs” represent opportunities for using ecosystem service values. Certainly, there may be state policies that explicitly prohibit consideration of trade-offs and we do not have a sense of how prevalent that may be, but we found ample evidence in three states of the scope for using ecosystem service values. In Section 6.2 below, we provide a recommendation related to addressing this opportunity at the state level.

Finally, there seems to be some interest in a “total value of an ecosystem” concept. As we noted in the report, total economic value (TEV) is a relevant concept as long as it relates to a valuing an incremental change in an ecosystem on a service by service level. The “total value” of an ecosystem, however, is not a relevant concept. Nevertheless, our discussions with policy-makers indicated some interest in generally understanding “what an ecosystem is worth.”[39] Furthermore, the value information that state policy-makers need is closely aligned to providing this information to constituents or stakeholders rather than on making decisions.

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[39] ERG has provided a recommendation under our “observations” below to address this.

Ecosystem service values may best be used to <u>guide</u> decisions rather than <u>make</u> decisions.

Based on our review of the documents from three states and our discussions with the three states, we see a role for ecosystem service values in guiding decisions rather than on determining what decision to make. In the former (guiding decisions), economic values are used as one input into a decision making process. In the latter (making decisions), the economic values are the used as the deciding factor for a course of action (e.g., whatever has a larger value would be selected). For one, state laws are often clear on priorities and they often require a balancing act; this means that using ecosystem service values as the deciding factor may not be supportable in the law. Second, ecosystem service values are subject to variability and uncertainty in measurement. Thus, using ecosystem service values to decide on a course of action may be problematic.

There are good and detailed databases that provide ecosystem service values with the ESP/TEEB and GecoServ databases offering relatively comprehensive coverage of the currently available estimated values.

The review performed by East Carolina University provided information on the currently available databases and related tools for valuing ecosystem services. Based on that information, summarized in Section 3, we can conclude that good and detailed databases are available that provide value estimates. Furthermore, the ESP/TEEB database and the GecoServ database are clearly the most relevant for NOAA's purposes, are the most up-to-date, and the most comprehensive.

There are significant gaps between what policy-makers could use and what's currently available.

As we noted above, there are opportunities for using ecosystem service values and there are good databases. However, there are gaps between what's needed from a policy- and decision-making side and the estimates that are available from the databases. Mangroves and coral reefs are two ecosystems where economic value estimates are readily available. For beaches, recreation-related estimates are also readily available. Some services for wetlands have fairly good coverage, but many do not. For other coastal-related ecosystems, there significant gaps in the currently available estimates of ecosystem service values.

6.2 Observations

There is a need for guidance for policy and decision-makers to show them the opportunities for *using* ***ecosystem service values in their work.***

Our review of state documents and discussions state policy- and decision-makers identified ample opportunities, but we also see a need for NOAA to develop guidance for policy- and decision-makers to identify those opportunities to use ecosystem service values. Our review involved a context analysis of some key state-level documents. In our review, we specifically looked for wording and phrases that reflected opportunities to use economic analysis or to assess trade-offs among competing interests. We recommend that NOAA provide state and local decision-makers with guidance on how to do this assessment to identify opportunities. The guidance would include terms and phrases within state policies that imply economic trade-offs be considered, but also being explicit that any time a policy requires weighing options or assessing impacts related to coastal resources, ecosystem service values can potentially be used.

There is a need for guidance for policy-makers to use ecosystem service values in an informed way.

In addition to being able to identify opportunities to use ESVs, policy- and decision-makers need guidance on how to use ecosystem service values appropriately. This guidance would include clear definitions and how to use values in decision-making. The guidance should cover approaches to generating estimates including benefit transfer methods. A theme throughout the guidance should emphasize the need for accessing appropriate economic expertise. A valuable approach in this regard would be to include cases studies and examples that state policy-makers can relate to.

The understanding and acceptance of benefit transfer methods may be a stumbling block for more widespread use of ecosystem service values in decision and policy-making.

As part of our discussions with state managers, we discussed whether benefit transfers would be an acceptable form of a values to use within their states. The Massachusetts and Hawaii officials felt that if used appropriately, benefit transfers would be acceptable; however, the person from North Carolina was doubtful about their acceptance in his state, especially if the value were from outside of the state. Furthermore, in our experience, benefit transfer tends to be a poorly understood concept. This is important since we expect that most use of ecosystem service values in policy- and decision-making would need to come using benefit transfers. Certainly, original estimate are possible; however, developing original estimates is costly and takes time. We believe many contexts at the state or local level would require timely information on value or would not have resources available to develop estimates, making benefit transfer the most viable option in many cases. Thus, a general conflict exists: on the one hand, there is a need for using benefit transfer, but benefit transfers have limited acceptance. This, in general, will be problematic for state and local policy- and decision-makers in being able to apply ecosystem service values.

There is a need to address "value" at an ecosystem level rather than at a service level.

State managers we spoke with continually expressed a need to understand value at an ecosystem level. As discussed in the text of the report, it is possible to assess "total economic value" where an incremental change in an ecosystem is applied to multiple services in the ecosystem and values are estimated at the service level and a total is "added up" from the service-level values. State managers appear to be drawn to the idea of getting a sense of what an ecosystem is "worth." Thus, there are two needs to be addressed. First, NOAA needs to help state managers understand the validity of the concept of TEV and the invalidity of a "total value" concept. Second, NOAA needs to consider how to help state manager address this need.

The lack of available ecosystem service values estimates in many areas will limit the ability to use ecosystem service values in policy and decision-making.

Our review found serious gaps in coverage of coastal-related ecosystem services. Even if NOAA can address the recommendations we make above to assist policy-makers and improve knowledge, there would still be limits on what could be valued based on these gaps. In that sense, our final recommendation (below) addresses gaps.

NOAA should review the gaps we identified and identify ways to fill those gaps.

To be able to effectively apply ecosystem service values in policy- and decision-making, estimates are needed. As it now stands, significant gaps exist in the available estimates. We recommend that NOAA identify ways to fill some of those gaps. Filling the gaps will involve studies being done to estimate values. NOAA should consider way to encourage studies to fill the gaps. This can include funding grants and/or fellowships, working with other grant funding sources (e.g., National Science Foundation) to prioritize the gaps, or providing data or other resources to researchers to assist those researchers.

SECTION 7: REFERENCES

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