

An Assessment of the Use and Potential Use of Ecosystem Service Valuation (ESV) within NOAA

A Report to the NOAA Science Advisory Board

From the Ecosystem Sciences and Management Working Group

April 2016

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Executive Summary

NOAA requested the Ecosystem Sciences and Management Working Group (ESMWG) to review its use of ecosystem service valuation to assure it is using the most appropriate methods and applying them effectively in decision support across the agency's many mandates and areas of responsibility. The ESMWG established the Ecosystem Service Valuation (ESV) task force to respond to this request and this task force identified an approach which included: reviews of different applications of ESV across NOAA and how these were used (or not) to inform decisions; reviews of enabling legislation and documents that describe the decision-making contexts within which ESV might play a role or that mandate considerations of economic benefits and costs; semi-structured interviews with NOAA staff involved with the application of ESV across the agency; and reviews of scientific literature describing ESV methods as well as extant federal guidance related to ESV and economic analysis.

The report identifies a number of findings and recommendations. Some key findings and recommendations include:

- NOAA has the capacity to conduct high-quality ESV, particularly in a few targeted areas (e.g., fisheries). However, NOAA currently lacks the internal capacity (particularly in social science) to apply high-quality ecosystem service valuation broadly across the Agency, and to significantly expand applications of ESV.
 - Although there is increasing discussion of ESV across the agency, a large proportion of direct applications are to recreational and commercial fisheries.
 - The frequent highlighting of individual ESV success stories across the agency can obscure the fact that comprehensive ESV (outside of a few targeted services) is rarely implemented.
 - Reliance on “one-off,” isolated studies of individual ecosystem services—while useful to inform (or highlight the value of) NOAA activities in specific cases—is unlikely to have a meaningful influence on the way NOAA approaches its mission.
- The practical impact of recent federal mandates to incorporate ecosystem services information “where appropriate and practicable” is reduced by individual agency and line office decision-making contexts which, as currently established, often restrict the role of ESV.
 - Constraints in the capacity to conduct ESV imply that the direct relevance of these estimates—or the capacity to use ecosystem service valuation to meet line office mandates—will be an important determining factor in the use of ESV.
 - There is a need to clarify exactly when and how ESV is relevant to specific decisions made by NOAA, including how the scale of ESV matches the scale at which decisions are made. This requires a move away from general, vague mandates to “consider ecosystem services.”
 - There is a need to reconcile management mandates with ESV—such that ESV has an impact on decisions.

- Ideally, ESV should be implemented in a way that is organic and central to NOAA's mission and the context of agency decisions, and that helps inform and enhance decision-making. Given the constraints facing the agency, however (e.g., current structure of the line offices, decision-making contexts, resource constraints, lack of social science capacity), there is a concern that ESV will be conducted *pro forma* in order to meet new mandates.
- Greater attention is needed to the assessment of the validity of different methods for ESV, as related to the need for accuracy in different decision contexts. The *perceived* validity of some methods within the agency does not reconcile with the *objective* validity of these methods as evaluated by the scientific community. The distinction between perceived and objective validity/accuracy is particularly relevant for methods such as stated preference valuation, different methods for benefit transfer, and the use of off-the-shelf decision-support tools.
- There is a need to better distinguish measures that may be interpreted as appropriate measures of economic value, versus other economic or monetary measures (e.g., jobs, economic impacts) that do not reflect economic values.
- There is a concern that too much emphasis is placed on off-the-shelf decision support tools that rely on some of the least accurate methods for ESV, particularly with regard for economic aspects of valuation.
 - Given current practice in these tools, even the best developed should be used when more accurate methods are infeasible, and when inaccurate estimates of value are acceptable.
 - Care is needed to distinguish tools and methods that generate valid and consistent measures of ecosystem service value, versus methods that generate monetary and non-monetary metrics that are not meaningful as economic value measures.
- Valid and accurate ESV requires the direct involvement of natural science and economic experts from the outset, to ensure that integrated methods are applied from initial scoping through data collection and analysis.
 - Valuation is about human behavior (trade-offs / responses). It is important to incorporate the human behavioral responses as part of the overall context of the ecosystem services assessment and decision-making approach.
 - The construction of the "ecological production function" in various contexts (EBFM, IEA, policy analysis, etc.) is among the most challenging issues limiting the application of economic analysis including valuation.
- It is often reported that accurate measurement of ESV can inform and improve decision making. A corollary to this statement is that in certain cases incorrect or suboptimal decisions may be made if ESV is not used. Without incorporation of the most significant market and non-market values into decision making it is possible to select options or policies that are not the best for society.
 - In the case studies section the Klamath case illustrates that inclusion of the passive use values (or total economic values) generates a different outcome in terms of the benefit cost analysis than when these values are excluded. Thus excluding relevant ESV can result in inaccurate information from benefit cost analysis.

- In general there is a risk of making the incorrect decision regarding investments (e.g., restoration investments), policy decisions or regulatory actions if significant ESV is excluded.
- Among the most important steps that can be taken by the agency is development of careful and clear recognition—across the whole of NOAA—of:
 - Whether and how ESV is relevant to different types of decision contexts that occur at different spatial and temporal scales,
 - How ESV can be integrated as an organic and core part of NOAA’s mission, and in what areas this makes sense,
 - The types of methods suitable to measuring different types of values, and the true advantages and disadvantages of these methods,
 - What additional capacity—at a minimum—is required to address new mandates for ecosystem services research within the agency?

An Assessment of the Use and Potential Use of Ecosystem Service Valuation within NOAA

Final Report

April 2016

Report Objectives

NOAA requested the SAB Ecosystem Sciences and Management Working Group (ESMWG) to review its use of ecosystem service valuation to assure it is using the most appropriate methods and applying them effectively in decision support across the agency's mandates and areas of responsibility. The ESMWG drafted a Terms of Reference (Appendix I) to outline its response to NOAA and discussed this plan with NOAA; the objectives of this report are the result of these discussions:

- To review the use of ecosystem service valuation within NOAA (and with its partners) to assure the agency is using methods that are appropriate to different types of decision-making contexts, and applying these methods effectively in decision support across the agency's many mandates and areas of responsibility.
- To provide guidance on the application and applicability of specific types of ESV methods within specific decision-making contexts, and how the variation in these methods can be incorporated into management advice. This includes an evaluation of the extent to which ESV is consistent with regulatory and other frameworks within which decisions are made (e.g., does a decision-making process provide a role within which ESV can be meaningfully considered).
- To evaluate the extent to which different agency decision-making contexts are consistent with the use of ESV, and how ESV can be best applied to meet agency needs.
- To examine the Agency's current capacity to conduct ESV of the type needed to inform Agency decision-making needs.
- To assess the most pressing needs for data and models to support ESV in NOAA decision processes.
- To evaluate areas in which updated, consistent methodological guidance would help NOAA prioritize application of ESV across the agency to provide needed information.

Methods

This report relies on data gathered from a number of different sources, including:

1. Reviews of different applications of ESV across NOAA and how these were used (or not) to inform decisions,
2. Reviews of enabling legislation and documents that describe the decision-making contexts within which ESV might play a role, or that mandate considerations of economic benefits and costs,
3. Semi-structured interviews with NOAA staff involved with the application of ESV across the agency [Appendix 2],
4. The scientific literature describing ESV methods,
5. Extant federal guidance related to ESV and economic analysis.

Overview

Broad policy guidance suggests that ecosystem service valuation should play a role in several areas within NOAA, particularly to support decision making and trade-off analysis. The National Ocean Policy Implementation Plan states, for example, under the Science and Information section, that an action for 2014 will be to “identify and collaborate with an ongoing project to employ public input and use socioeconomic and natural sciences to identify, develop, and apply valuation frameworks for ecosystem services” (National Ocean Council, 2013, Appendix p. 27). The Next Generation Strategic Plan states “to achieve this objective, NOAA will expand and maintain a reliable and accessible suite of climate, weather, ocean, marine ecosystem, and living marine resource and geospatial information, to improve the understanding of key environmental processes—including occurrence and effect of high impact events— and build capacity in the social, behavioral, and economic sciences to support the valuation of ecosystem services, risk and vulnerability assessments, and decision-support services” (NOAA, 2010, p. 25). The 2011 President’s Council of Advisors on Science and Technology (PCAST) states that “Federal agencies with responsibilities relating to ecosystems and their services (e.g., EPA, NOAA, DOI, USDA) should be tasked with improving their capabilities to develop valuations for the ecosystem services affected by their decision-making and factoring the results into analyses that inform their major planning and management decisions” (PCAST, 2011, p. iii). The recent memorandum outlining policy guidance on incorporating ecosystem services into federal decision making (OMP/CEQ/OSTP, 2015) directs federal agencies to incorporate ecosystem services into decision making frameworks including, where appropriate, monetary valuation of ecosystem services.

The findings of the ESV task force, based on reviews of agency documents, peer review literature and discussions with individuals in NOAA suggest that there are tensions between the agency-wide proscription to broadly incorporate ecosystem services and ESV into agency decision-making and the decision-making contexts across different parts of the agency. In many cases these contexts are incompatible with—or at least present challenges to—the use of mandates or other policies with respect to ESV that have to be taken into consideration when deciding whether and how to apply ESV methods. Clarifying these challenges and identifying solutions (where needed) can help promote more efficient and relevant use of ESV to inform decisions. Our findings suggest that there are few areas of NOAA in which ESV is clearly prohibited or inconsistent with the agency’s mission. However, the applicability and relevance of ESV varies across the agency. While there are many areas in which ESV can help make more informed decisions, there are others in which the capacity of ESV to inform decisions is

more limited. Insights such as this can help the agency prioritize limited resources to support ESV in areas where it is most useful.

Purview of this Report: Economic Valuation of Ecosystem Services

A number of definitions of ecosystem services, and ecosystem service values, exist in the literature. These include approaches that consider value as reflected in human preferences and behavior, including economic or monetary values, along with other approaches that eschew anthropocentric approaches to focus on “values” based on energy, complexity or the functioning of ecological systems (Holland et al. 2010). There are also different perspectives on what constitutes an ecosystem service, and what distinguishes ecosystem services from other aspects of ecosystems (see, for example, the discussion in Olander et al. 2015 and in the Federal Resource Management and Ecosystem Services Guidebook FRMES Guidebook, <https://nespguidebook.com/>). This report does not debate or compare these alternative perspectives. Rather, the goal of this report is to consider *economic or monetary valuation of ecosystem services as practiced within NOAA*. This focus is consistent with the use of ESV as part of regulatory impact and cost-benefit analysis within US federal agencies, as reflected in individual agency reports and guidance materials (e.g., NMFS 2007; US EPA 2009, 2014) and related OMB Circulars (e.g., Circulars OMB A-4 and A-94). It is also consistent with extant federal guidance on ecosystem services analysis noted above, including that from the 2011 President’s Council of Advisors on Science and Technology (PCAST) and the recent OMB/CEQ/OSTP (2015) Memorandum outlining policy guidance on incorporating ecosystem services into federal decision making. This emphasis does not imply that economic valuation of ecosystem services is the only or even most applicable approach to ecosystem service valuation, but rather that it is a quantitative approach to valuation fully consistent with current guidance to US federal agencies.

Ecosystem service valuation (economic or otherwise) is only one of many approaches to evaluate the impacts of federal agency actions, and should be considered in concert with other forms of quantitative and qualitative information available to decision-makers. Full-scale ESV may not always be possible, advisable or even allowable; depending on the decision-making context (we discuss this issue in greater detail below). As noted by the FRMES Guidebook (Section 3: 60), “the difficulty of putting a dollar value on all ecosystem services is well understood among practitioners and is the reason that OMB guidance suggests that assessments should monetize what is possible to monetize, quantify what cannot be monetized, and describe what can be neither monetized nor quantified for regulatory rule making.” Hence, the focus on economic valuation in the current report—consistent with the same focus in the FRMES Guidebook—does not imply that other information on ecosystem services cannot or should not be considered. To the contrary, we strongly recommend that quantitative information on ecosystem service values be considered ONLY within a broader context of additional, non-economic qualitative and quantitative information, and that economic information on ecosystem services be considered alongside information provided by other natural and social sciences. Future ESMWG efforts may wish to address other perspectives on ecosystem services.

What are Ecosystem Service Values?

To guide the discussion we adopt a relatively simple set of definitions, recognizing that there are alternative views of these issues.

Ecosystem services: Services provided by nature/ecosystems that benefit humans. The set of services that improve the well-being of humans ranges from foods to recreational experiences to aesthetics. There is considerable discussion regarding such issues as whether ecosystem services need to directly benefit humans or if the pathways can be indirect, and questions about the breadth of the services (e.g., EPA Science Advisory Board, 2009).

Value: There are a number of concepts of value. They range from value reflected in human preferences, including economic or monetary values, to values associated with energy or ecological systems that are not based on human preferences. For the purposes of this report we will focus on values as they are experienced and expressed by humans, and we will describe two categories of value: monetary (economic) values and non-monetary values (see U.S. EPA , 2009 for details on these topics). Monetary (economic) values are amounts of money that an individual (or group) would be willing to accept in exchange for the reduction of (or change in) an ecosystem services, or be willing to pay for the improvement of (or change in) an ecosystem service and be as well off as before the change. Parallel measures of value can be derived for firms. They express, in monetary terms, the trade-offs associated with the change. Non-monetary values are other ways of expressing value (quantitative or qualitative) that do not involve monetary equivalents.

Types of Economic Value: Economic values can be market values (expressed through exchanges in markets) or non-market values (for goods and services that are not traded in markets). Economic values can also be categorized broadly into “use” values and “passive use” values. Use values are values that are expressed or reflected in actual behavior (purchasing items, engaging in recreation trips, etc.). The behavior illustrates that scarce money and/or time resources are expended on an activity that is associated with ecosystem services. Passive use values are values for ecosystem services that are not reflected in behavior. Values for improvements in threatened species populations, for example, are not commonly observed in behavior.

Ecosystem service valuation: Ecosystem service valuation, in the context of economic values, is the measurement of monetary values associated with changes in an ecosystem service. This could include the value of an increase in fish harvests (e.g., to recreational anglers, fish consumers or commercial fishers), or the value of improved water quality for swimming, or values associated with improved population status for endangered species. ESV can also be assessed in non-monetary or qualitative ways.

Economic Valuation Methods: Some of the tension and confusion around the use of economic values for decisions making arises from questions about the validity and reliability of some of the valuation

methods. Valuation methods are categorized as revealed preference (based on market choices or choices that have financial consequences) or stated preference (based on structured surveys that elicit monetary value measures). Examples of revealed preference methods include hedonic price methods (decomposing the price of market products into various components including environmental quality measures), and travel cost methods (assessing the value of activities such as recreation trips using the travel cost as a proxy for price). Stated preference methods include techniques called contingent valuation and choice experiments. These are methods that typically ask respondents to choose between the current situation and an alternative that includes an environmental improvement and a payment in increased taxes or other relevant payment type. Revealed preference methods can be used to measure use values while stated preference methods can measure use and passive use values. A commonly used approach when primary data collection is not possible (due to cost, time, or scale of the issue) is “benefit transfer”, which employs the transfer of ESV measures from other areas and/or times periods to the area of interest.

When does ESV apply to the decision making context and when can it be used most productively?

At its core ESV is about measuring the human benefits (or costs) provided by ecosystem changes, generally in economic terms. Given this, the extent to which ESV can inform various types of decisions depends on whether the statutory, regulatory or other contexts within which these decisions are made enables information on benefits and costs to influence decisions. If there is no channel through which information on benefits and costs can influence decisions, ESV will have limited impact. The question is where is ESV most effective, and where does it make most sense to allocate resources to performing ESV?

Consider the following examples illustrating the application of ESV in regulatory and decision making contexts. ESV is directly applicable or required for Natural Resource Damage Assessment under the Oil Pollution Act (OPA)/ CERCLA / National Marine Sanctuaries Act (NMSA). It is also applicable in certain circumstances in the Endangered Species Act in the determination of critical habitat or recovery strategies. ESV is required in regulatory impact assessment under EO 12866, but the assessment can be qualitative in nature (see the Klamath Case Study below). The National Environmental Protection Act (NEPA), Executive Order (EO) 12866 (Regulatory Impact Review) and the Regulatory Flexibility Act may require quantitative assessment of ESV. The MSA includes components that link to ESV and clearly fisheries are an important ecosystem service – but issues surrounding the MSA are discussed in a case study below.

ESV is also applicable in IEAs and EBM as it can facilitate analysis of options by characterizing trade-offs. Trade-off analysis is listed as one of the elements that is often missing in exercises like coastal and marine spatial planning (Collie et al., 2013).

In principle, ESV will be most useful in decision making contexts as a trade-off analysis tool or as a means to assess the relative net benefits (i.e., benefits minus costs) of alternative actions. Use of ESV in benefit cost analysis, where the analysis includes relevant market and non-market values, can facilitate the determination of the option / policy with the highest net social benefit.

The remainder of this report (1) describes the context for ESV within NOAA, focusing on agency mandates and the “demand” for ESV, (2) provides case studies of the use of ESV within NOAA, (3) provides advice on “best practices” for ESV, (4) examines and addresses capacity for ESV within NOAA, (5) identifies potential areas for expanded use of ESV, and finally (6) outlines tensions regarding ESV and provides advice surrounding ESV within NOAA.

The Context for Ecosystem Service Valuation within NOAA

This section places ESV development in NOAA in the current context of the economics and decision making literature for the environment. It addresses the status of formal mandates and formal administrative guidance documents that apply to ESV in the federal government in order to assist in understanding subsequent discussion of how NOAA is developing its approach to ESV and ESMWG recommendations. Through this brief exposure it can be seen that the mandates are weak in terms of requiring formal assessments but quite permissive and encouraging toward such developments in terms of improving environmental decision making through administrative guidance.

What is the demand for ESV? A growing body of literature argues that the monetary and non-monetary value of services provided by ecosystems to humans should be taken into account in decision-making (Daily et al., 2009; Scarlett and Boyd, 2011; Laurans et al., 2013, Lipton et al., 2014; Chaudary et al., 2015 Posner et al., 2016). Government agencies are developing capacities for assessing ESV as part of best practices for decision making, improved capacity for decision making and for other purposes. Even though there is uptake of ESV among federal agencies, a strict legal analysis would likely show there is no clear mandate that requires agencies to incorporate ESV into decision processes or to make institutional changes in decision-making that rely more heavily on ESV (e.g., Kalen, 2010). While there may be many opportunities to use ESV to improve federal decision making, it is unlikely at present that the federal government could be sued successfully for failure to perform ESV. One area where broader issues of value are being taken into account is with respect to natural resource damage assessments under the provisions of the Oil Pollution Act (OPA), the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the National Marine Sanctuaries Act (NMSA). Under these provisions liability is established in statute for injury to publically owned natural resources and efforts are made to calculate the compensation due the public.

What are NOAA's roles in ESV? NOAA, as the lead oceans agency of the federal government, has a broad sweep of regulatory, management, research and monitoring responsibilities assigned to it by Congress for management and protection of US coastal and marine ecosystems as well as forecasts of weather and climate. Established under Executive Order 11564 in 1970 as part of a reorganization of the federal government by President Nixon, NOAA lacks an Organic Act establishing the agency and laying out its management authorities and responsibilities. In contrast to other federal agencies with founding legislation, NOAA operates under a complex web of legislation and funding authorities that have accreted over the years. Consistent with other agencies NOAA operates under a complex set of administrative procedural rules in some cases imposed by Congress and others by the President that guide, for example, how such things as economic assessments, including ESV are to be considered in planning and decision making.

What are the legislative mandates relevant to NOAA? The formal Congressional mandates for NOAA's management and protection responsibilities reside in, for example, the Fish and Wildlife Coordination Act (FWCA), the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), the Coastal Zone Management Act (CZMA), the Magnuson-Stevens Fishery Conservation and Management Act (MSA), OPA, and CERCLA. While the management actions deal inextricably with marine ecosystems,

nowhere in any of these Acts is the two word text “ecosystem services” actually used nor are ecosystem services explicitly required to be understood and valued as part of management and protection. One might argue that because Congress has not reauthorized these key legislative bases since the early to mid-2000s the emerging broader discourse has not been incorporated into formal requirements. The upshot is that NOAA is neither required to use ESV in its decision making nor is it prohibited from so doing except with respect to its responsibilities under the ESA and the MMPA. Thus, within NOAA the discourse surrounding ESV and efforts to apply it are increasing (Lipton et al., 2014).

Congress has provided a legal and regulatory process framework through which continuing discourse on ESV takes place across all federal agencies. Most powerfully this is seen in assessments under the National Environmental Policy Act (NEPA) which require disclosure of (cumulative) environmental impacts of agency actions and analysis of alternatives. In order to assess trade-offs among alternatives other social and economic assessments may be performed. Similarly the Regulatory Flexibility Act, the Unfunded Mandates Reform Act, Information Quality Act, and the Paperwork Reduction Act contain requirements for assessments that certainly can contribute to ESV while still not specifying “ecosystem services” directly. The Office of Management and Budget (OMB) severely constrains the ability of NOAA researchers to perform surveys with respect to stated preference methods according to interviews with NOAA experts.

What are the administrative guidelines for NOAA and ESV? In the permissive environment absent of Congressional mandates, formal guidance encouraging and disciplining the use of economic valuation (including ecosystem service valuation) is led by the Executive Branch of the government starting at the highest level in Presidential Executive Orders and carried out by the Office of Management and Budget, Council on Environmental Quality and Office of Information and Regulatory Affairs.

Chief among the Presidential Executive Orders that apply to all economic assessments by federal agencies are EO 12866 “Regulatory Planning and Review” and 13563 “Improving Regulation and Regulatory Review.” These documents provide technical guidance on how economic assessments can be developed and used. In addition to these Executive Orders, the Office of Management and Budget has issued its own circulars to better communicate how it interprets these EOs as found in Circulars OMB A-4 and A-94. Again, neither of these circulars specifically refers to ESV but provides guidance on how analyses contributing to ESV are to be carried out. OMB expects these to be part of any economic regulatory impact assessment any federal agency carries out (OMB website: https://www.whitehouse.gov/sites/default/files/omb/inforeg/regpol/RIA_Checklist.pdf).

In addition to the EO the Presidential Memorandum on Scientific Integrity, March 9, 2009 sets forth a very broad commitment to use the best available scientific information across federal agencies. Each agency is expected to develop its own commitment to the principles in the Presidential Memorandum and NOAA has done this with NOAA Administrative Order (NAO) 202-735D: Scientific Integrity. None of these documents expressly names “ecosystem services” as an element but clearly the intent is to encourage and advise economic valuation practices that support assessment of ESV.

Within NOAA, line offices like the National Marine Fisheries Service have further refined NOAA policies and guidance to specific activities like economic assessments in fisheries management (NMFS,1997; NMFS, 2007).

NOAA has not been alone among marine federal agencies struggling to implement ESV (e.g., Scarlett and Boyd, 2011; Schaefer et al., 2015; Keysar, 2011; EPA, 2009).

Making the connection between the general guidance for best economic practices in regulatory assessments and ecosystem services is the Presidential Executive Order 13574 which calls for the development of coastal and marine spatial plans to improve regional decision making at all levels and calling for the “preservation of ecosystem services” at all levels. EO 13574 has led to the development of the President’s US Ocean Action Plan (<http://ocean.ceq.gov/actionplan.pdf>) and the Ocean Policy Implementation Plan (NOC, 2013). Further cementing the ecosystem service concept into federal decision making, the Directors of OMB, CEQ and the Office of Science and Technology Policy (OSTP) issued a Memorandum [M-16-01, October 7, 2015] for executive departments and agencies entitled, “Incorporating Ecosystem Services into Federal Decision Making.” This document ostensibly complements all existing authorities but definitely directs agencies to develop and institutionalize policies for ecosystem services assessed using a range of qualitative and quantitative methods (OMP/CEQ/OSTP 2015).

The Memorandum lays out a six month timeframe for agencies to submit descriptions of their activities and work plans to CEQ [March 30, 2016] and sets forth implementation guidance to occur over the next 14 months including peer review. In many ways, this initiative is aspirational and provides a test of the executive administration’s resolve to inculcate ecosystem services, and ESV, into the culture of federal agencies. [Note carefully that Memorandum M-16-01 expresses the will of the current President but, unlike a Congressional mandate that is codified into law and regulation, it is not subject to legal challenge and a future President can alter or eliminate it.]

Examples of Ecosystem Service Valuation and Decision Making

What are some examples of the use of ESV within NOAA (and related agencies) that can help illustrate where improved information for decision making is made available by quantification of ecosystem services (ES) and changes in ES as well as valuation of ES (ESV)? How were these cases / decisions informed about the use of ESV (reports, simulation models, etc.)? Are there examples where ESV was not used but could have been (i.e., improved information to support decision making would have been generated)? Conversely, are there cases in which ESV has been conducted or proposed, but did not have a clear role in decision-making? In the following section of the report we provide a small set of examples of the use of ESV in NOAA and related agencies and relate the discussion of the case studies to the broader issues of the use of ESV for decision making and management.

Klamath Dam Removal Case Study

Introduction

The Klamath River basin in Oregon and California covers an area of approximately 12,000 square miles and has had a history of natural resource use associated with the river system including irrigated agriculture, hydropower, fisheries, recreation and other activities. Infrastructure in the basin includes four dams that began operation between 1922 and 1962 as well as the storage structures and canal systems associated with these dams. Over the past decade there has been a decline in fisheries as well as a series of challenges with water quality and quantity. Federally recognized tribes in the region have been affected in various ways including loss of access to traditional fisheries. Conditions in the region have also had an impact on the listing of Coho salmon under the Endangered Species Act. The four facilities were facing relicensing which included concerns about the costs of compliance with Federal Power Act and Clean Water Act requirements. These conditions resulted in the development of two agreements that would examine the removal of the four facilities or dams (Klamath Hydroelectric Settlement Agreement or KHSA) and undertake a set of actions to improve fisheries, and generate benefits to Indian tribes in the region as well as local communities (Klamath Basin Restoration Agreement or KBRA). The evaluation can be summarized as the assessment of two scenarios; no implementation of the KBRA and no removal of the dams versus removal of the dams and implementation of the KBRA. (U.S. Department of the Interior, 2012).

Policy / Decision Making Context

The examination of the program included an analysis of the impact on National Economic Development (NED) of the options – a benefit cost analysis of the market and non-market values that would be affected under the two scenarios. The NED analysis provides input to the decision regarding the choice of scenario (with dam removal and KBRA versus without dam removal and KBRA).

Ecosystem Service Valuation

A number of different ecosystem services are affected differently in the two scenarios, each resulting in benefits or costs to different user and nonuser groups. While it is not possible to measure all possible ecosystem service values affected by the proposed changes (no matter how small), a variety of assessments were conducted to quantify the major ecosystem service benefits and costs. Commercial fishing is expected to benefit from the dam removal scenario – market valuation methods can be used to quantify associated economic values. Recreational fisheries (in-river and ocean) are also expected to improve in the dam removal scenario (relative to no dam removal). The recreational values of these changes can be measured using non-market valuation techniques. Irrigated agriculture is also expected to improve under the dam removal and KBRA. Other forms of recreation are also expected to improve. Because the removal of dams and the KBRA have the potential to improve threatened species survival probabilities, stated preference methods were used to measure the non-use values. Stated preference methods were also used to measure total economic value (the combination of use and non-use values) associated with the dam removal and KBRA (relative to no dam removal and no KBRA). Hydropower benefits would be reduced with dam removal (a cost) and benefits of reservoir recreation would also be

lost with dam removal. Other costs include the cost of removal and mitigation of dam removal impacts, and the KBRA program would also generate costs associated with the restoration in the region. The analysis illustrates the wide range of ecosystem services affected by the change and the need to measure the bio-physical and monetary impact of the change to accurately assess the benefits and costs of the removal program.

Results

The benefit cost ratio is approximately 9:1 in the most conservative cases and approximately 48:1 in the case where high benefit estimates are compared to low cost estimates. These values suggest that the removal program and KBRA are economically efficient and would generate an increase in net economic benefits. Interestingly the largest categories of benefits are those associated with non-use values and total economic values. Use values (market and non-market) are two to three orders of magnitude smaller than non-use or total economic value estimates. If only use values were included in the analysis it is unlikely that the dam removal program would be viewed as economically efficient (positive net benefits). This illustrates a common pattern in such evaluations—the ability to quantify non-use ecosystem service benefits often is a deciding factor in whether proposals pass a benefit cost test.

Implications

The quantification of ecosystem service values in this context provides a mechanism to compare the two scenarios and evaluate the net economic benefits associated with the dam removal program. The majority of the categories of benefits and costs are non-market in nature (e.g., forms of recreation) and the largest value estimates arise from non-use and total economic value estimates that include considerations of threatened species improvements, fish habitat improvements and benefits to local Indian tribes. Accurate measurement of these values, or their inclusion/ exclusion, has a significant effect on the measurement of net economic benefits and would likely have an impact on the decision context.

A Limited Role of Ecosystem Service Valuation: The Example of Fish Stock Rebuilding

Despite an increasing focus on ecosystem services quantification and valuation across different areas of NOAA—mirroring guidance by the President’s Council of Advisors on Science and Technology (2011)—there is a lack of clarity regarding whether and how different types of ecosystem services analysis reconciles with the mission of different NOAA programs. For example, while ecosystem services valuation (ESV) can inform a wide range of decisions made within the Agency, there are at least some decision contexts for which enabling legislation or related standards preclude or limit the influence of ESV. Greater clarity is required on the particular role, or reason for exclusion, of ESV within different areas of the Agency’s mission.

Some types of decisions made by NOAA are well suited to—and could be better informed by—information on ecosystem service values. An example is the Analysis of Alternatives (AOA) conducted by regional Fisheries Management Councils to inform fishery management plans. However, beyond direct values associated with recreational and commercial fisheries, ecosystem service values are rarely

quantified. A number of guidance documents are relevant for the scope and nature of economic analysis used to evaluate fisheries management plans. These include NMFS' Operational Guidelines: Fishery Management Plan Process (NMFS, 1997), Guidelines for Economic Reviews of National Marine Fisheries Service Regulatory Actions (NMFS, 2007), and Guidelines for the Assessment of the Social Impact of Fishery Management Actions (NMFS, 2007). The Operational Guidelines require an analysis of the beneficial and adverse ecological, economic and social impacts of potential management options on the fishery as a whole, "in monetary or qualitative terms..." (NMFS, 1997, p. A-38). These Guidelines address the general nature and objectives of the economic and social impact analysis, including that changes should be considered "relative to the status quo" (pg. A-39). Guidance is also provided on the types of economic effects that should be considered within AOAs (NMFS, 2007; p. 13-22). For example, the guidance document states that, "economic analysis related to the performance of the relevant commercial and recreational users, non-consumptive users, processing sector, and retail or other market sectors is needed" None of this guidance requires ESV nor are ecosystem service and other relevant values incorporated into analysis of the economic welfare effects of policy options. While analyses of producer and consumer values associated with changes in fishing activity are often modeled, welfare effects related to other ecological changes are generally overlooked or characterized only in qualitative terms. Hence, ecosystem service values are considered (in that harvestable fish are an ecosystem service), but only in a limited way.

Fish stock rebuilding is an example of an area in which ESV has an even more limited role. As described by the Committee on Evaluating the Effectiveness of Stock Rebuilding Plans of the 2006 Fishery Conservation and Management Reauthorization Act (2014), the rebuilding of fish stocks is guided by §304(e) of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) and the National Marine Fisheries Service (NMFS) guidance on Magnuson-Stevens Act implementation, as reflected in the National Standards. The declaration of a fish stock as overfished triggers immediate, prescribed remedial actions. Under the provisions of the MSFCMA, rebuilding plans for overfished stocks should take no more than 10 years, except when certain provisions apply. These provisions are determined by biological criteria, including the stock specific potential rate of rebuilding and the allowable time period for rebuilding specified in the Act and associated National Standards. Exceptions to these mandates are limited.

With few exceptions, economic factors—including ESV—may only be considered after the biological parameters of the rebuilding program, in particular the rebuilding biomass target and maximum time to rebuild, have been met. These factors are generally evaluated within AOA that presents the data, models, and analysis of the socioeconomic trade-offs associated with the required reductions in fishing mortality. Hence, ESV can only influence the choice of fish stock rebuilding plans within a narrow range of possibilities determined by the biological criteria codified within MSFCMA and the National Standards. Because of this, economic analysis often plays a relatively minor role in fish stock rebuilding plans. Where ecosystem service values are considered, they are almost always limited to those associated directly with commercial and recreational harvest. This issue is discussed in more detail by the Committee on Evaluating the Effectiveness of Stock Rebuilding Plans of the 2006 Fishery Conservation and Management Reauthorization Act (2014, chapter 6).

Variations in the extent to which ESV reconciles with the mission and enabling legislation or regulations applicable to different parts of the Agency suggests that a broad mandate to “consider ecosystem service values” will have variable salience across NOAA. In some cases, more systematic consideration of these values can promote decisions that better support the public interest (e.g., by promoting higher value uses of ecosystems and natural resources). In other cases—such as fish stock rebuilding—enabling legislation and accompanying regulations explicitly limit the degree to which information on ecosystem services can be considered. This variability suggests the need for more clear recognition of areas in which ESV can and cannot support Agency decisions.

The Role of Ecosystem Service Valuation within Coastal Habitat Restoration

In concept, coastal habitat restoration represents a context within which ecosystem service valuation could play a significant role. When combined with information on restoration costs, comparison of values provided by different habitat restoration alternatives enables the identification of alternatives that generate the greatest net social benefit (Schultz et al., 2012). However, aside from a small number of notable exceptions, ecosystem service valuation is not conducted to support or inform habitat restoration efforts, at least not in a comprehensive manner that captures a broad range of non-fishery related ecosystem services that can be affected by restoration efforts. Where ecosystem service “valuation” has been conducted, it has often quantified measures such as job creation and avoided costs or other measures not directly linked to economic benefits (e.g., Edwards et al., 2013; Kroeger and Guannel, 2014). Although such measures can be useful, they do not reflect well-defined measures of ecosystem service value (Holland et al., 2010). As emphasized by a prior ESMWG review of NOAA’s coastal habitat restoration efforts (NOAA ESMWG, 2014, p. 2), “many of NOAA’s RFPs and decision criteria for project identification and funding focus on multiple benefits and ecosystem services, but it appears that there is little focus on measuring these benefits.” A review of the data in the National Estuaries Restoration Inventory (NERI, <https://neri.noaa.gov/neri/>) conducted for the prior ESMWG review, moreover, found “real concerns in data quality” (NOAA ESMWG, 2014, p. 3), casting into doubt the accuracy of valuations based on these data.

The prior ESMWG review did find that NOAA has given significant attention to the measurement of fisheries objectives and benefits, mirroring a similar focus on these benefits across many line offices. However, focus on fisheries benefits alone is likely to be inadequate for coastal habitat restoration projects, because the small scale of most restoration projects implies that “the benefits to fisheries productivity are likely to be low (or non-existent) or at the very least very difficult to measure” (NOAA ESMWG, 2014, p. 4). Similar challenges apply to other types of ecosystem service values such as shoreline protection (Barbier et al., 2013); although the collective effect of coastal habitats may be substantial, the effect of any one (small) restoration project may be difficult to ascertain. The appropriate scale for ecosystem service valuation is an ongoing challenge (Johnston and Wainger, 2015). The difficulty conducting ecosystem service valuation for small restoration projects was echoed during our interviews of NOAA staff involved with habitat restoration. In cases such as these, some other types of (non-fisheries) ecosystem services may be larger and more readily valued, particularly when considering small projects (e.g., on-site recreation). However, even though restoration projects are often chosen for non-fisheries benefits, these ecosystem service values generally remain unmeasured.

Recommendation 6 of the prior ESMWG report (“NOAA restoration efforts should more clearly measure additional benefits beyond fisheries”) reflects the general lack of attention to quantified, non-fisheries ecosystem service values provided by NOAA’s direct and indirect habitat restoration projects.

The relevance of more extensive use of ecosystem service valuation to NOAA’s habitat restoration efforts depends on three key factors. First, does the decision-making context provide a mechanism whereby quantified measures of ecosystem service value are relevant to the decisions that are made (e.g., sites that are chosen, restoration methods that are used)? Second, is the scale of restoration such that ecosystem services can be defensibly quantified? Third, does the Agency have the data, capacity and resources to conduct valuation at a sufficient level of quality and accuracy to support the decisions to be made (Kline and Mazzotta, 2012)? Where answers to these three questions are ‘yes,’ ecosystem service valuation could be used to help better inform NOAA’s restoration efforts.

Green Infrastructure

Numerous recent events have fueled interest in the development of “green infrastructure” as alternatives to grey infrastructure. The August 2015 report of the Committee on Environment, Natural Resources and Sustainability of the National Science and Technology Council on Ecosystem Service Assessment Research Needs for Green Infrastructure, developed in response to Hurricane Sandy’s impacts, highlights the interest and importance of this topic. This report, which focuses on coastal green infrastructure, describes the need to understand three components: identification of ecosystem services that can provide protection services, quantification of the contribution of changes in ecosystem service provision, and valuation of these services (CGIES, 2015). The report emphasizes the need for best practices in valuation and also leans towards the use of benefit transfer because of the expense of primary data collection for valuation.

Green infrastructure is the management of natural systems (e.g., wetland restoration, restoration of forests or marsh systems, salt marshes and sand dunes, permeable pavement) to achieve benefits that are typically generated by physical capital investments such as flood protection, improvement of water quality and other outcomes. Interest in green infrastructure has arisen in part because of the interest in investigating alternatives to constructed systems, but also because of the perception or realization of potential co-benefits associated with such investments (Barbier, 2011). Co-benefits may include aesthetics, recreation, biodiversity or other aspects of green infrastructure. The measurement of flood control (or related) benefits of green infrastructure and the presence of these potential co-benefits links green infrastructure to the use of ecosystem service values for decision making.

There are two levels of consideration regarding the use of ecosystem service values in green infrastructure analysis. One is whether the green infrastructure investment itself is economically efficient. For example, would the economic benefits of restoration or retention of wetlands for flood protection be greater than the costs? Second, would the green infrastructure be the “best” option when compared with all options available including grey infrastructure (or “hybrid” infrastructure)? The literature has typically focused on the first question, while in a formal benefit cost analysis both of these

issues are important. While there are a number of case studies in the literature, this discussion focuses on two; the analysis of flood control by the US ACE (Kousky, 2015) and the cases presented in Eastern Research Group (2015) for NOAA. These cases illustrate the use of ecosystem service valuation in the evaluation of green infrastructure and some of the potential pitfalls and challenges.

Kousky (2015) examines five “green” flood control projects in New England. Each case included a benefit cost analysis conducted by US ACE. The key findings in the context of ESV are the following. The studies focused on the benefits of flood control (reduced damages) and, of the five cases, in only one case did the economic benefits exceed the costs. This illustrates the potentially important role of evaluating the full suite of ESV to fully assess green infrastructure projects. The “promise” of green infrastructure appears to be in the multiple benefits that arise, and these cannot be fully evaluated unless they are measured. It still could be the case that these projects would not pass a benefit cost test even with other ESV included, but the information provided would be more complete. Other assessments (e.g., Buss, 2005) describe projects where benefits exceeded costs, but inclusion of the full suite of benefits was necessary to realize this outcome. The comprehensive review by Abt and Associates (2014) of three Coastal Restoration cases illustrates that co-benefits in some cases are substantial and result in very high benefit cost ratios while in other cases the overall benefits remain modest. Clearly each case must be evaluated on its own merits.

A second finding from the Kousky (2015) analysis was the importance of the baseline assumptions in the with-without framework of benefit cost analysis. The assumptions regarding the level of economic development that would occur in the absence of the flood control project, particularly on the land areas being considered for restoration, are critical. These assumptions highlight the need for information on expected economic conditions, and expected impacts on market and non-market values, with and without the project. Perhaps not surprisingly, the only case that passed the benefit cost test was a case in which a large population base would be affected by flooding, and that this population would grow substantially over time, reducing the area for potential green infrastructure development and increasing the potential flood damages. This also highlights the need to focus analysis on those cases where impacts affect large numbers of people.

Eastern Research Group (2014) (see also Eastern Research Group, 2015) outlines the process for evaluation of green infrastructure projects (benefit cost analysis) and presents two case studies in the Great Lakes region. The case studies include two flood control assessments; one in Duluth, MN and one in Toledo, OH and in addition to damage reduction assessments the case studies included the evaluation of the non-market value of changes in recreation associated with the green infrastructure projects. In both cases, the economic analysis shows that the benefits do not exceed the costs, at least when a 20 year time horizon was employed. Interestingly, the non-market recreation benefits (estimated using benefit transfer and projections of recreation activity levels with and without flood control) comprise 20% of the benefits. The authors repeatedly emphasize the other non-market elements are not included, but it is not clear how significant these would be. The main lessons learned from these case studies include: (1) that non-market ESV can reflect a substantive portion of the economic benefits of such projects, but that they are often based on benefit transfer measures or not included in the benefit cost analyses (see also Kousky et al., 2011), and (2) that green infrastructure investments may not be

economically efficient, especially in the short term, and that case must be taken in assessing the benefits and costs of these projects. While the tone of the literature regarding green infrastructure is very positive, these few case studies illustrate that they, much like any infrastructure investment, must be assessed carefully.

The review of green infrastructure projects provides a number of other key insights. First, as identified in the CGIES (2015) report, benefit transfer is heavily relied on in the assessment of green infrastructure projects. Best practices in benefit transfer are required, but it is also the case that without sufficient primary valuation studies benefit transfer will be less accurate or effective. Given the importance of green infrastructure investment analysis as a response to climate change there could be consideration of an investment strategy to conduct primary valuation studies in those areas where current studies are limited or where particularly unique and important values are required. The benefit transfer of beach recreation values, for example, relies on a relatively large number of studies. Transfers of more unique values associated with location or activity specific ecosystem services will not be able to benefit from such a large number of studies. Second, there is a significant danger in benefit transfer of double counting, or of using “per-acre” or per unit area values inappropriately. Ecosystem service values are not easily transferred to a per unit area basis as they depend on the location of the ecosystem and the people benefitting from these activities. This challenge is highlighted in the discussion by Barbier et al. (2011) where they refuse to report values in “common units of measure” (Barbier et al., 2011, p. 173), such as constant dollar per hectare units, because that may lead to the simple addition of benefits per unit area which ignores specifics about the location, population and the substitution or complementarity between services. Abt and Associates (2014) handle this issue quite carefully in their reporting of valuation estimates. They identify where overlaps are likely to occur between value estimates and avoid simple addition of value measures. Note that there are many examples in the literature where this is not the case.

Third, most studies highlight the uncertainty associated with the “ecological production function” or the linkage between the infrastructure investment and the final ecosystem services. There is a need for improved science team-based analysis of such projects so that the linkages between ecosystem services, and the linkages between natural and human systems, are more accurately assessed. Valuation has, to a large degree, been conducted in a silo rather than as an integrated component of the overall assessment of the outcomes of a process of investment in ecosystem restoration or change. Green Infrastructure investments will be more accurately assessed with more integrated analysis of the projects. A final issue raised in the reviews of green infrastructure investment analyses is that the distribution of benefits must also be considered. In some regions the benefits of coastal protection may appear to be relatively small because the region is characterized by low income communities. In this context valuation and benefit cost analysis can help describe such cases and raise questions about the use of measures to address the distribution of environmental benefits.

There is a significant and growing literature on ecosystem service values associated with coastal hazards, adaptation and shoreline change that might be used to inform NOAA efforts in this important area. Despite this work, there are still many unknowns regarding the benefits and costs of different

approaches to coastal hazard mitigation that affect ecosystem services, and most green infrastructure projects proceed with little or no defensible information on ecosystem service co-benefits.

Best Practices in Ecosystem Service Valuation

Economic valuation of ecosystem services implies the systematic quantification of social benefits in commensurable (typically monetary) units, using methods grounded in economic theory. A basis in economic welfare theory is one of the primary distinguishing features of economic valuation. This underlying theory provides the formal structure necessary to link changes in ecosystem services to estimated monetary values to changes in social welfare. Many measures that can be quantified in monetary terms are not well-defined measures of economic value; the theoretical structure and rules of economic valuation ensure that economic values have a consistent interpretation, regardless of the specific application.

There are several guides to established best practice in non-market and ecosystem service valuation in the literature (Champ et al., 2003; Freeman et al., 2014; Holland et al., 2010) and guidance documents (e.g., NESP, 2014 (recently updated with a 2016 version); US OMB, 2003; US EPA, 2014; US NMFS, 2007). Valuation can be conducted at differing levels of accuracy, depending on factors that include the reasons for the analysis (more accurate values are required for some types of applications; Kline and Mazzotta, 2012), data availability, time and resources necessary for the analysis, expertise available to conduct the analysis, and regulatory approvals that may be required (e.g., OMB approvals for many types of data collection and regulatory analyses (cf. Iovanna and Griffiths, 2006).

The intent of this section is not to provide a detailed description of best practices for specific methods or for the use of valuation in benefit cost analysis in general. However, a brief summary of best practice guides is provided, followed by a discussion of strategic advice on the use of ecosystem service valuation in the type of decision frameworks that NOAA faces.

Best Practice Guides for Valuation Methods

Overview of Valuation Tools:

A large number of guides to the literature on non-market valuation are available and many have been recently updated. Some are more theoretically oriented while others are more focused on empirical analysis and implementation. Among the notable books that include comprehensive discussions of stated and revealed preference approaches are Freeman et al. (2014), Haab and McConnell (2002) and Champ et al. (2003, with a new edition to be released soon). Lipton et al. (2014) provide a review of the valuation methods used in NOAA cases. A comprehensive web-based tool available for resource agencies and manager is NESP, 2014, <https://nespguidebook.com/> (referred to as the Federal Resource Management and Ecosystem Services Guidebook FERMES Guidebook). This guidebook contains overviews of the use of an ecosystem services approach in the context of Federal guidelines, examples of use within agencies, as well as details on valuation methods. A very brief description of valuation methods with illustrative NOAA application is provided below.

Table 1. *A Partial Summary of Valuation Methods, Types of Values Measured, Illustrative NOAA Applications, and Limitations/Concerns.*

Method	Type of Value Measured	NOAA Examples	Limitations / Concerns
Contingent Valuation	Passive Use Values (threatened species improvement) Value of Oil Spill Damages	Mansfield et al., 2012 Carson et al., 2003	Extent of Market; Strategic Behavior; Scenario Descriptions / Communication.
Choice Experiments	Passive Use Values: Values of Attributes of Threatened Species Conservation Programs	Wallmo and Lew, 2015	Extent of Market; Strategic Behavior; Attribute Definitions / Communication
Choice Experiments	Use Values: Marginal Values of Improvements in Recreational Fishing Experiences	Jarvis, 2011; Lew and Larson, 2012	Strategic behavior; Attribute Definitions / Communication; Linkages to Actual Behavior (choice set definition; impact on frequency and choice); Sampling / Response Bias
Travel Cost Models	Use Values: Recreational Fisheries Models	Lipton and Hicks, 2003; Haab and Hicks, 1997	Linkages to Actual Behavior (choice set definition; impact on frequency and choice); Sampling / Response Bias; Endogeneity / Omitted Variables Bias
Hedonic Property Models	Use Values: Impact of Flooding (Damages)	Braden and Johnson, 2004	Endogeneity / Omitted Variables Bias; Choice Set Definition; Sorting
Benefit Transfer	Use Values: Lost Recreation Use Value	Byrd et al., 2001	Availability of Primary Studies (similar environmental change, similar human population, etc.)

When is Valuation Necessary?

In some cases valuation is required, or at least strongly supported, to address a mandate. Regulatory impact assessments developed through EO 12866 and EO 13563 typically require quantitative assessments of benefits and costs. Natural resource damage assessments (NRDA), especially in the case of highly significant damages, employ primary valuation approaches or benefit transfers. NRDA can also employ habitat equivalency analysis or use relatively simple transfers (unit day transfers).

Valuation may be necessary in cases where there are difficult trade-off decisions to be made and the scale of the project, program or policy is significant. When there are multiple values that move in opposite directions (e.g., enhanced aesthetic value but reduced market value from fish) valuation can help assess the trade-offs and identify “winners and losers.” Valuation could also be helpful in decision support tools to help quantify, in commensurable units, the net effects of scenarios where multiple values are changing simultaneously. This is the goal of tools such as Marine InVEST (Guerry et al., 2012; Plummer et al., 2014; Karieva et al., 2012) although note that tools such as these have a variety of potential shortcomings (see discussion below). Valuation could also be used in ecosystem based management as a mechanism to incorporate social systems into marine / coastal ecosystems. In the ESMWG review of coastal marine spatial planning (Collie et al., 2013) it was identified that a goal of several CMSPs was to integrated economics into the decision support components. Valuation would be an integral element of such tools.

Since primary valuation studies can be costly, the use of such studies will depend on the scale of the assessment (in the case of policy or program) or injury (in the case of damages) (see Lipton et al., 2014). Consideration must be given to proportionality of the investment in analysis relative to the problem or case.

Monetary valuation methods should not be used when mandates preclude their use – although there is debate in the literature about whether such exclusions are beneficial (e.g., Plantinga et al., 2014). In cases such as endangered species analysis cost-effectiveness analysis is often employed as it does not use monetary values but examines only the costs of alternative approaches to achieve the environmental goal. But the case has been made that benefit cost analysis (including valuation) could provide significant insights and results in a better overall allocation of scarce conservation resources (Ando, 2015; Plantinga et al., 2014). When there are no data on the ecosystem service values in question, or limited knowledge about the impact of ecosystem services (the ecological production function) then analysts should be cautious with the use of monetary valuation. Finally, when the scale of the impact or change is very small, it is unlikely that primary valuation will be feasible.

Choosing the Right Valuation Methods:

The valuation method chosen depends on the changes in ecosystem services arising from the policy or program change. In the Klamath case study, for example, a large number of ecosystem services were affected (recreational fishing, passive use values associated with endangered species, etc.). In these cases multiple valuation methods may be warranted, although the analyst must be careful not to double count. Keeler et al. (2012) provide a comprehensive assessment and set of examples that outline the

mapping between impact, change in ecosystem service, and valuation method used. Holland et al. (2010) provide a similar description in the context of the specific example of reduced acreage of salt marsh. In most cases it would be impossible to construct estimates of all affected ecosystem services when there are as many as identified in Keeler et al. (2012). In such cases the analyst will need to determine which services will be the most significant in the decision framework. Scoping assessments, perhaps using benefit transfer, could be used to guide the identification of the most important ecosystem service values to measure.

In some cases multiple methods may provide estimates of the same value. Freeman et al. (2014) provide a matrix of valuation methods and ecosystem service categories. Stated preference is applicable in almost all cases, while specific revealed preference methods are required to address changes that can be identified through changes in behavior. This means that there is often a choice between stated and revealed preference methods (or both can be employed and data fusion can be explored – although such practice is relatively uncommon.). Revealed preference data and valuation methods have the advantage that they are based in actual choices and there is considerable confidence in these methods. But if the change being examined is outside the range of current data (e.g., quality change outside the range of the current data series) or if many elements of quality are highly collinear, yet in the policy case only a single quality change is to be assessed, then stated preference methods should be employed. Clearly if passive use values are to be measured, only stated preference methods can be employed.

Generating Valid and Accurate Results

The material presented below provides a discussion of the “state of knowledge” of valuation methods and validity/accuracy. This is not an exhaustive review but it attempts to capture the main elements associated with each valuation method. Readers not interested in the technical detail can skip this section, but we hope it is informative. Note that there are few examples of guidelines or protocols like this for ecosystem service valuation as a whole. The Swedish Environmental Protection Agency (Naturvårdsverket, 2006) created such a guide but it is now somewhat outdated.

i. Market values.

Most discussion of valuation in the context of ecosystem services tends to concentrate on non-market valuation. However, this does not mean that market value should be treated lightly, nor should it be thought that developing estimates of market values is easy. It may be relatively easier to generate estimates of market values, but several pitfalls exist. A significant advantage of market goods valuation is that for relatively small changes the economic value is the product of price times the quantity increased. But if the change is large, or if the market is not perfectly competitive (e.g. subsidies exist) then market prices will not reflect the marginal willingness to pay and adjustments must be made (see Boardman et al., 2010 for more detailed discussion). Nevertheless, market values are typically less controversial in ecosystem services assessment.

ii. Stated preference methods:

Stated preference methods fall into several categories, essentially depending on whether the method describes the change in ecosystem service in terms of attributes / characteristics or as

scenarios. Stated preference methods can be used to elicit values about privately consumed non-market goods (e.g. recreation experiences) or public non-market goods / services (e.g., protection of habitat for threatened marine species). Stated preference methods may be implemented using mail surveys, in-person interviews, internet panels, or mixtures of methods. There is considerable controversy around the survey method, especially associated with OMB rules regarding survey research. Recent overviews of the methods include Freeman et al. (2014), Kanninen (2007), Bateman et al. (2002) and Champ et al. (2003). While the literature abounds with discussion about the merits of alternative approaches for stated preference valuation, we focus here on the key points of controversy that arise in the use of stated preference for valuation in the context of decision making. Many of these points are summaries of the forthcoming set of guidelines for stated preference research (Johnston et al., 2015).

a. Are stated preference estimates of value valid / reliable?

The question of validity seems to be an overarching concern in the use of stated preference. There continue to be debates in the literature regarding this issue (e.g., Kling et al., 2012; Hausman, 2012; Haab et al., 2013). The main message for users of valuation information is that there has been a considerable change in the literature on validity of stated preference estimates over the past decade. The literature has generated rigorous tests of the conditions under which validity is expected, and a number of tools that can be used to help develop valid estimates of value (Vossler et al., 2012; Carson et al., 2014). The bottom line is that a great deal more is known about validity than in the past. It is now relatively clear that stated preference for public goods cases can be valid if the respondent faces the incentives to respond truthfully (feels that their response will influence the policy outcome and that they will actually have to pay the amount stated). These conditions to a certain degree can be assessed. There is more uncertainty about the use of stated preference for the measurement of the value of private goods, since the incentives to reveal truthful preferences are more difficult to construct, but there is some confidence that measures of the marginal value of private goods (e.g., the improvement of fish catch rates in an overall recreation experience) can be valid. The question of whether stated preference as a whole is valid or not should be ignored. The question is whether the particular application of stated preference provides the appropriate incentives to generate valid responses (Haab et al., 2014).

b. What mode of surveying respondents should be used?

The issue of mode in surveys is very context specific, but there are concerns with any method regarding the degree of selection bias, social desirability bias, and the limitations of some methods for conveying the information required in a stated preference survey. Some main recommendations, however, are the in-person surveys are not necessarily the best approaches, and the internet panels that employ probability sampling may be very useful (while those that employ non-probability sampling such as opt-in panels, may be questionable). The latter issue is important in the context of OMB approval of stated preference methods for decision making.

c. What are the main uncertainties associated with the use of stated preference?

While many users of stated preference studies are concerned with overall validity, there is also considerable concern about the method employed (attribute based or not), the payment vehicle (taxes versus other vehicles), or the survey mode, there are other factors that may have a much larger effect on value measures. Among the most important of these is the determination of the extent of the market. In many cases the goods being valued are public goods and the benefits can accrue overall a large distance (potentially the entire country). The choice of the extent of the market, or the accounting stance (in the benefit cost literature) has a much larger effect in these cases than the choice of details within the method. Sanchirico et al. (2013) clearly illustrate the implications of different choices of the extent of the market in the context of marine mammal protection and Mansfield et al. (2012) illustrate the impact of this choice on the regulatory assessment associated with the Klamath dam removals. In addition to the extent of the market, the method of aggregating values, in particular if there is concern about selection bias, can have a significant effect on the aggregate value used in the decision making context. Finally, there is concern about the measurement of passive use values – values that do not have associated behavioral trails. There are questions about whether respondents would actually pay the amounts for a species or habitat that they may not have known about before the survey. But these are exactly the issues that are examined in the determination of validity of stated preference measures discussed above.

d. Best practices:

1. Rely on the latest literature for summaries of best practices and guidelines – e.g., Johnston et al. (2015) guidelines document. Issues include:
 - a. Definition of scenarios / attributes, and payment vehicles
 - b. Methods to address strategic behavior
 - c. Experimental design (costs, attribute levels, etc.)
 - d. Econometric analysis
 - e. Reporting
2. Peer review surveys / instruments
3. For policy relevant studies – strive for representative samples / methods to mitigate or assess nonresponse bias. Address the question of the extent of the market.
4. Design stated preference projects so that they can be long lasting (reporting, multiple value elicitation, etc.).

iii. Revealed preference methods

Travel cost models:

The most popular revealed preference method applied to the assessment of ecosystem services related to marine and aquatic systems is the travel cost model. This method constructs a behavioral model of whether individual participate in recreation, how often they participate, where they choose to participate, and how these decisions / choices are affected by changes in quality, availability of recreational sites and other features. The “travel cost” is employed as a proxy for price and thus the method is consistent with the theoretical base in economics associated with demand functions / systems. In most cases only a subset of the behaviors described above are explored because of a lack of data or a focus on a specific question.

While the travel cost model is a well-defined and often used method for assessing the value of impacts on recreation activities, there are surprisingly few documents that provide guidance on best practices. Among the more notable references are Parsons (in Champ et al., 2003 and 2016 forthcoming), Phaneuf and Smith (2005), Freeman et al. (2014). But one of the earliest guidance documents was a 1983 NOAA technical guidance document by Dan Huppert (1983). While much has changed in the literature in terms of modeling capability and data availability since 1983, the principles outlined by Huppert still have merit and are paraphrased below, along with some new guidelines for implementing or assessing travel cost models.

a. Best practices:

1. Employ a framework consistent with economic theory.
2. Define the problem in terms of an issue of a quality change in a recreational site or a change in access, and the activities that will be affected. This will help in determining the model type and the data required.¹
3. Carefully define the alternatives and the choice set.
4. Identify how multi-purpose and multi-day recreation trips are handled.
5. Incorporate socio-economic factors affecting the choices. These can then be used if forecasts of the values under future socio-economic conditions are required.
6. Consider the impact of the methods of data collection on demand estimation and value measurement. High quality databases that are well documented in terms of their sampling processes and potential for selection bias should be used. NOAA’s Marine Recreational Information Program (MRIP) provide a great deal of documentation on data collection and

¹ Approaches to approximate ecosystem service values when data are scarce are outlined in Adamowicz et al., 2011.

quality, relative to recreation demand surveys that are employed in specific projects or programs and are not systematically collected over time. However, there is a need for improved systematic data collection on recreation activities that are affected by marine / aquatic ecosystem services beyond recreational fishing. (See Lipton et al., 2014 for a review of data sources for travel cost / recreation demand analyses in NOAA).

iv. Hedonic Price Methods:

Hedonic price methods have not been widely used in cases in NOAA but they may be relevant in a number of contexts including the evaluation of the benefits of restoration that generate aesthetic benefits and/or flood control. Large databases that integrate property characteristics along with local environmental conditions are being developed. Some of these are being used to develop measures of the value of environmental amenities when individuals “sort” themselves by moving to neighborhoods with characteristics that they find desirable or influencing the supply of characteristics, such as environmental improvements, in their neighborhoods (see Kuminoff, 2013). The responsiveness of housing prices to environmental characteristics provides a very useful way to identify the marginal value of changes in ecosystem services.

But the measurement of accurate marginal values is challenging. Statistical models of property value can suffer from omitted variable bias, endogeneity, collinearity, and functional form uncertainties. Best practice in this area relates to the use of high quality databases, careful definition of the market area over space and time, a great deal of sensitivity analysis to attempt to assess robustness to choices of functional form and specification, and if possible analysis in a quasi-experimental context (Bockstael and McConnell, 2007; Taylor, 2003). Good examples of the latter include Muehlenbachs et al. (2015) who develop estimates of the impact of hydraulic fracturing on property values using a difference-in-difference approach.

Nation-wide comprehensive sorting models that relate changes in coastal environment, and climate to housing choice, migration and employment are a future research frontier. These models incorporate changes in environmental quality (e.g., sea level rise) along with investments in public programs (e.g., infrastructure development) to develop models of housing / location choice that arise from endogenously generated housing, employment and investment in public goods. Additional discussion of this issue is presented in the section that discusses areas that should receive increased attention or should be areas of future research investigation.

v. Benefit Transfer:

In our discussions with agency personnel it is clear that benefit transfers are often employed in economic analysis when it is conducted in NOAA. Furthermore, there are now several databases of ecosystem service values (EVRI, Oceaneconomics (National Ocean Economics

Program), etc.) that are available to researchers for use in economic analysis. While our knowledge of benefit transfer has advanced a great deal over the past 25 years (see Johnston et al., 2015) it is clear that transfer errors (the error in transferring values from one site / time period / policy study to another) are still relatively large even in the best of cases. Transfer errors average 36 to 45% but can be as large as hundreds of percent (Johnston et al., 2015). Thus these should be viewed as a second best option to primary studies.

Johnston et al. (2015) describe the state of the art in benefit transfer as characterized by the following four elements: (1) A large number of high quality, well documented, primary valuation studies are required for benefit transfers, (2) the scale (geographic size) and scope (change in environmental quality) of the analysis in the studies to be transferred need to be similar to the case the transfer is being applied to, (3) the ecological and socio-economic characteristics of the sites must be similar and (4) the transfer of a value function (that includes factors that influence the value such as socioeconomic characteristics and environmental quality measures), is better than single estimates of value. Johnston and Wainger (2015) describe the application of benefit transfer methods to ESV, along with a discussion of the choice between primary studies and benefit transfers for different types of applications.

Ecosystem Service Values versus Other Economic Measures:

Ecosystem service values are values constructed in a consistent economic conceptual framework that reflect the aggregation, over people, of their willingness to pay (or willingness to accept compensation) for a specific change. A host of other economic measures also exist. Many of these are useful in assessing the change in market economic activity that arises from a change in program or policy, but these other economic measures should not be used in benefit cost analysis or other similar assessments. Measures of regional job creation or regional expenditure change are not valid welfare measures as they do not reflect the monetary measure of benefit derived by those affected. A recreational angler's expenditures may increase with a reduction in quality if that angler now has to travel farther to achieve the same level of satisfaction from fishing. Another measure often discussed in the literature is the use of replacement costs as measures of value. Replacement costs describe the cost of replacing the lost or damaged ecosystem service using other methods (e.g., investments of human or physical capital). But the replacement may not provide an exact substitute, it may not be the least expensive way to replace the services, and most importantly, replacing the service with the human or physical capital may not be what would be optimally done (or what society would be willing to pay for) if that option was available (Bockstael and McConnell, 2007)

Off-the-Shelf Valuation Tools:

Recently a number of valuation "toolboxes" have been developed. There is a concern that too much emphasis is placed on off-the-shelf decision support tools that rely on some of the least accurate and defensible methods of ESV, particularly with regard to economic aspects of valuation. We urge caution in the use of such tools, without considerable knowledge of the underpinnings of the model. For

example, these tools can at times generate transfers of “per unit area” measures of value that have little relationship to the ecosystem service change being studied. Ecosystem service values are seldom constant per unit area as they depend on the population of people affected and the change in the ecological conditions. More generally, most of these tools forecast values that are invariant to at least some factors that should, according to economic theory, affect value. These factors include the characteristic of beneficiaries, marginal values that diminish as more of an ecosystem service is provided, the effects of substitutes and complements, and spatial factors such as distance. Given current practice in these valuation or decision-support tools, even the best developed should be used only when more accurate methods are infeasible and only when inaccurate estimates of value are acceptable. Care is also needed to distinguish tools and methods that generate valid and consistent measures of ecosystem service value, versus methods that generate monetary and non-monetary metrics that are not meaningful as economic value measures. Finally, any “black box” tool should be avoided entirely, as there is no way to verify whether valid methods have been applied to quantify value.

Summary of Best Practices:

The key messages in this section are: (1) employ the appropriate valuation methods, which will involve identification of the key ecosystem service changes. This outcome would be best achieved by incorporating the economic analysis into the assessment of the policy or program change from the very beginning; (2) employ measures of value that are consistent with economic theory – if the purpose is to measure monetary values for benefit cost analysis or related analyses; (3) use judgement to invest resources into valuation that are proportional with the degree of importance of the change in ecosystem services and the scale / scope of the impacts. More accurate analyses will be required when there are difficult trade-off decisions to be made and where stakes are high (economic, social or ecological), and; (4) invest in communication about the methods used, the interpretation of the findings, and the use of the values in decision making. Benefit cost analysis, and the values that are employed in it, should not be viewed as a “black-box” for decision making but should be viewed as tools to help understand trade-offs and identify winners and losers. Laurans et al. (2013) and Rogers et al. (2013) highlight the lack of communication between policy makers and researchers / practitioners as one of the main stumbling blocks associated with the use of ecosystem service valuation in policy and decision making (see Eastern Research Group, 2014 for related discussions).

Capacity for Ecosystem Service Valuation within NOAA

A Memorandum for Executive Departments and Agencies released on October 7, 2015 (M-16-01) directs agencies to “develop and institutionalize policies to promote consideration of ecosystem services, where appropriate and practicable, in planning, investments, and regulatory contexts,” and “directs agencies to implement aforementioned policies and integrate assessments of ecosystem services, at the appropriate scale, into relevant programs and projects, in accordance with their statutory authority.” This memorandum exemplifies a broader set of mandates and initiatives designed to encourage more widespread recognition and analysis of ecosystem services and ecosystem service values across US federal agencies (Schaefer et al., 2015). Not all ecosystem service analyses incorporate explicit economic valuation, and valuation is not always required to provide the information necessary to support federal decision-making (Schaefer et al., 2015). However, understanding the social benefits of ecosystem services and quantifying related trade-offs requires valuation—absent an analysis of social values, ecosystem service analysis is limited to quantifying what is valued, but not how much it is valued (Olander et al., 2015). The magnitude of these values is often at the heart of management and policy trade-offs, and cannot be formalized without valuation.

NOAA, like many federal agencies, has been engaged in a broad suite of activities to enhance the use of ecosystem services analysis and valuation within planning, investment, and regulatory decision-making. These efforts have prompted questions related to the capacity of the Agency to conduct this work, and what enhancements in capacity are needed. Similar capacity concerns are common across agencies. As noted by Olander et al. (2015), “failure [of federal agencies to quantify relevant ecosystem service values] may occur because of resource or time constraints, lack of agency staff expertise, lack of available data, or lack of confidence among agency staff in the methods used to measure different types of value.” However, it may also occur because of a potential disconnect between the statutory authority and mandates of various federal agencies (or components of these agencies) and their ability to conduct and use ecosystem service valuation—particularly more comprehensive valuation that considers a broad range of values flowing from affected ecosystems. Even if an agency or office has the expertise, data and resources to conduct ecosystem service valuation, it may not have the authority to use the resulting information to inform decisions and/or authority to fully manage the ecosystems under consideration. For example, in the context of fisheries management, comprehensive ecosystem service valuation (beyond direction valuation of managed fishery resources) is of limited utility in the absence of effective mechanisms for ecosystem-based fishery management.

There are no instances where NOAA is expressly precluded from conducting ecosystem service valuation. However, there are two types of capacity constraints that influence the ability of NOAA offices to capitalize on the information provided by ecosystem service valuation: (1) the capacity to conduct ecosystem service valuation, and (2) the capacity to use ecosystem service valuation to inform decisions. Although the first capacity constraint is often given considerable attention, the second constraint is equally if not more binding in many circumstances. Together, they represent a considerable impediment to an Agency-wide paradigm-shift towards greater and more comprehensive consideration of ecosystem service values.

Capacity to Conduct Ecosystem Service Valuation

The joint ecological and economic validity of ecosystem service value estimates requires expertise and data on the biophysical functions and outputs of ecosystems and ways in which these functions and outputs translate to goods and services that enhance human welfare (Johnston et al., 2012; Olander et

al., 2015). It is rarely the case that accurate ecosystem service valuation can simply be “built on top of” already existing biophysical data, or that biophysical measures can be multiplied by off-the-shelf measures of economic value to generate useful estimates (Boyd et al., 2015; Johnston and Wainger, 2015)—biophysical and economic components of valuation models must be developed in tandem. Such analyses require the capacity to conduct biophysical and economic components of ecosystem services analysis, together with the capacity (including time and resources) to coordinate these components.

Limitations in NOAA’s capacity to conduct various types of social science and economic analysis, including ecosystem service valuation, have been addressed (directly and indirectly) by multiple publications and groups over the past decade (e.g., Lipton et al., 2014; NOAA SSC, 2015; NOAA SSRP, 2003, NOAA SAB, 2009; Wiley et al., 2013). For example, as summarized by Wiley et al. (2013), p.6, “[NOAA] staff is consistently unable to keep up with the growing demand for social science. NOAA is unable to demonstrate quantitatively the effect of its actions on society’s wellbeing and economic productivity, even when anecdotal evidence of societal benefits is readily evident. A recent review of the Economic Statistics of NOAA found that there are very few studies that concretely quantify the way in which society utilizes NOAA products and services and even fewer that attempt to value these activities.”

Wiley et al. (2013) also identify multiple instances in which the capacity to conduct non-market and ecosystem service valuation is a particular concern for multiple line offices, in that the inability to conduct ongoing economic evaluations represents a barrier to success in meeting the agency’s goals. At the same time, Lipton et al. (2014) summarize many cases in which non-market and ecosystem service valuation have been used to support NOAA decisions. This apparent inconsistency suggests that NOAA has the capacity to conduct targeted, high-quality economic valuation, particularly in areas in which economic analysis is frequently conducted (e.g., NOAA Fisheries, which alone holds the majority of social science FTEs within NOAA (NOAA SAB, 2009; Pendleton, 2013). However, NOAA lacks the capacity (particularly in social science) to apply high-quality ecosystem service valuation broadly across the Agency, and to significantly expand applications of ecosystem service valuation. “Valuation of NOAA’s programs, products, and services, as well as valuation of ecosystem services, is a critical gap that cuts across all of NOAA” (Wiley et al., 2013, p.6). The frequent highlighting of individual ecosystem service valuation “success stories” across the agency can obscure the fact that comprehensive ecosystem service valuation is rarely implemented, and never on an ongoing basis.

More specifically, there is an important distinction between targeted, one-off case studies of ecosystem service values (including many of the works cited by Lipton et al., 2014 and in other summaries of ecosystem service valuation by NOAA, e.g., Efron, 2013; Roleau, 2014), and systematic, comprehensive ecosystem service valuation to inform ongoing decisions across the Agency. The Agency has the capacity and expertise to conduct isolated and targeted ecosystem service valuations at a high level of quality, particularly in key areas such as natural resource damage assessment and for narrow classes of ecosystem services such as recreational and commercial fisheries. An example is the frequently cited NMFS effort to assess the costs and benefits (including ecosystem service values) associated with the proposed removal of the Klamath River Dam (U.S. Department of the Interior, 2012). However, as suggested by reviews such as Pendleton (2013) and Wiley et al. (2013), NOAA currently lacks the capacity to expand these isolated studies to comprehensive, systematic and ongoing analyses of the impacts of decisions on ecosystem service values. Even current mandates for economic data collection and analysis remain unmet. For example, “the Agency is only meeting 55% of its commercial fisheries economic data collection requirements and roughly 30% of its recreational fisheries economic data collection requirements” (Wiley et al., 2013). Other line offices such as NOS similarly lack the social

science capacity to meet even current mandates, without requirements for additional ecosystem service valuation (Wiley et al., 2013). Further, there is a tension between ESV analysis to evaluate NOAA performance (program evaluation) and use of ESV to support NOAA's mission that may further fragment scarce resources. Amidst this inability to meet even extant data collection and analysis mandates, ecosystem service valuation will likely be conducted only in ways that directly respond to line office mandates, or for which there is a direct capacity to use ecosystem service valuation. Improvement in this situation will require enhancements in the capacity to conduct ecosystem service valuation across NOAA line offices and focusing on NOAA's mission.

Capacity to Use Ecosystem Service Valuation

Constraints in the capacity to conduct ecosystem service valuation (see above) imply that the relevance of these estimates—or the capacity to use ecosystem service valuation to meet line office mandates—will be an important determining factor in the use of ecosystem service valuation across the Agency. The frequently mentioned foundation for the relevance of ecosystem service values for federal agency decision-making is a variety of Executive Orders (e.g., 12866 and EO 13563) and OMB Circulars (e.g., A-4, A-94) that mandate cost benefit analysis for major federal actions. Individual agencies also have enabling legislation and internal guidelines that encourage or at least permit ecosystem services analysis of various types. However, “with limited exception, [US federal agencies] do not currently have the mandate to invest substantial resources and capacity in ecosystem services approaches.” Moreover, in the context of federal agency decisions, “an ecosystem services approach may not always result in a change in policy outcomes” (Schaefer et al., 2015). That is, the practical impact of broad federal mandates to incorporate ecosystem services information “where appropriate and practicable” is reduced by individual agency and office decision-making contexts which, as currently established, sometimes provide little role for comprehensive ecosystem service valuation.

For example, guidance documents that are relevant for economic analysis of fisheries management plans include Operational Guidelines: Fishery Management Plan Process (NMFS, 1997), Guidelines for Economic Reviews of National Marine Fisheries Service Regulatory Actions (NMFS, 2007), and Guidelines for the Assessment of the Social Impact of Fishery Management Actions (NMFS, 2007). The Operational Guidelines require an analysis of the beneficial and adverse ecological, economic and social impacts of potential management options on the fishery as a whole, “in monetary or qualitative terms...” (NMFS, 1997, p. A-38). Guidance is also provided on the types of economic effects that should be considered within an analysis of alternatives (AOA) for fishery management (NMFS, 2007, p. 13-22), including “economic analysis related to the performance of the relevant commercial and recreational users, non-consumptive users, processing sector, and retail or other market sectors.” Although broader evaluation of ecosystem service values is permitted by these guidelines, it is not mandated. Moreover, it is unclear whether and how this information would influence traditional fishery management AOAs and the subsequent Fishery Management Council decisions. In the absence of a clear link between the information provided by ecosystem service valuation and the decisions that are made, it is unlikely that ecosystem service valuation will be given high(er) priority across the Agency.

There are particular contexts in which ecosystem service valuation (or broader non-market valuation) has played a significant an ongoing role related to agency decision-making. For example, as summarized by Lipton et al. (2014), the NOAA Damage Assessment, Remediation, and Restoration Program (<http://www.darrp.noaa.gov/>) lists multiple case studies in which non-market and ecosystem service valuation efforts were conducted in support of federal natural resource damage assessment (NRDA) efforts. However, even in this case, the practical application of ecosystem service values is limited. As

summarized by Olander et al. (2015), federal NRDA's since 1989 have relied almost exclusively on "replacement costs" as the measure of damages (a measure with no relationship to ecosystem service value), with economic values used only as a basis for calculating interim losses. Moreover, in many cases, the resources that are damaged may be of types (e.g., small pocket tidal marshes) that are very difficult to assess using traditional ecosystem service valuation approaches. In such cases, analyses often revert to simpler analyses such as habitat equivalency analysis that have no concrete association with economic valuation.

The mandate and capacity to use ecosystem service valuation to inform specific decisions appears to be a primary impediment to the broader application of ecosystem service valuation within NOAA. To be sure, there are narrow cases in which ecosystem service values have been quantified for decades, such as values related to changes commercial fish harvests. However, there is a distinction between these long-established, targeted applications of economic valuation, and a paradigm shift towards broader, more holistic applications of ecosystem service valuation to inform and justify Agency decisions. Given binding resource constraints within NOAA—and particularly in the social sciences—this paradigm shift seems unlikely without a clear and direct link between quantified ecosystem service values and specific line office decisions (i.e., a clear capacity to use ecosystem service values).

This constraint was raised repeatedly in interviews conducted with NOAA staff across different line offices for this report, addressing the implementation and role of ecosystem service valuation within the agency. As noted by one interviewed expert in ecosystem service valuation, "the key question is whether and how having information on ecosystem service values would affect decisions that are made. In some cases the link is very clear, in other cases it is less so. Without that link, it is less likely that resources will be allocated to valuation. ... The primary issue is capacity and resources." Absent systematic assessments of ESV many decision processes within NOAA rely on stakeholder inputs with respect to economic or social impacts which in some cases identifies issues but may raise more questions than answers. ESV can discipline these stakeholder processes and provide invaluable assistance in decision processes about trade-offs.

Potential Future Applications of ESV with in NOAA

This section provides a few examples of analysis, research and/or data collection in the area of ecosystem service valuation that appear to be underrepresented in NOAA's portfolio of analysis. In some cases these are frontier issues while in other cases they are extensions or applications that would help inform policy. This is not a comprehensive list, but it is designed to illustrate the type of areas in which greater use of ESV could help inform decisions within the agency.

a. Value of Natural Capital:

Ecosystem service values are typically used in "local" cases for benefit cost analysis of programs or policies, or for natural resource damage assessment. However, an additional use of ESV is to develop an improved assessment of the value of natural capital for an assessment of wealth (including natural resource wealth). Such wealth assessments would be beneficial for reporting on whether natural capital in oceanic resources is increasing or decreasing and how changes in policy or programs could impact measures of natural capital.

The recent paper by Abbott and Fenichel (2014) examines the linkage between natural and social systems, focusing on fisheries, dynamics and policy change, to illustrate how changes in policy can contribute significantly to the wealth (capital value) embodied in fisheries resources. While their analysis employs ESV based on market values (i.e., value of fish) there are only efforts to expand the set of values that are included in the assessment of other components of natural capital (e.g., WAVES program – Wealth Accounting and the Valuation of Ecosystem Services, <http://www.wavespartnership.org/>). Analyses of this type can inform policy by describing the linkage between policy changes and natural capital value – a component of overall wealth. That is, the most relevant feature of these models is not the “total value,” but rather the change in value over time due to NOAA actions.

b. Equilibrium sorting models of the coastal residential choice:

Nearly 40% of the U.S. population lives in a county on a shoreline / coast (<http://oceanservice.noaa.gov/facts/population.html>) and this percentage has been rising over time. These locations provide amenity services (beach use, visual amenities, etc.) but they also may be at risk from climate change or other changes in environmental quality. Changes in policy or environmental quality will be reflected in property values. Analysis of impacts of climate change, or impacts of policies to attempt to address environmental quality, may best be studied using equilibrium sorting models – an approach that has arisen from hedonic property value models and models of migration in response to public goods / amenities. These models characterize residential location choice while incorporating the fact that location decisions involve employment considerations as well as a variety of amenity services (education quality, air quality, water quality, etc.). Furthermore, the levels of public goods are affected by individual demand for such services and they affect future provision of such services. Sorting models attempt to address these endogenous relationships in developing estimates of the economic value of policy changes, or the impact of environmental quality changes, on location patterns. A review is provided by Kuminoff et al. (2013).

A few examples of such models focusing specifically on climate change and sea level rise include Husby et al. (2015) and Bunten and Kahn (2014). These approaches can help identify the impacts of environmental change along coastlines in terms of migration / population location decisions, monetary values, and assess the distributional impacts of such changes. A finding often reported in this literature, for example, is that lower income individuals tend to locate in poorer environmental quality (or high risk) neighborhoods because of the trade-offs made and the sorting process. Thus, these models can provide considerable information on the impact of policy or environmental change for both economic efficiency and equity analyses.

c. Analysis of the distribution of impacts of policy / practice changes:

ESV is usually carried out in the context of benefit cost analysis and informs the question of the efficiency of policies (which policy option generates the highest aggregate economic

benefit). However, an important criterion in policy analysis is the distributional impact of the option. Are lower income people disproportionately affected? Are vulnerable populations adversely affected? There has been relatively little use of ESV for distributional analysis, even though conceptually the data and empirical methods could be used to address such questions. Sanchirico et al. (2013) construct what is effectively a regional distributional analysis of the benefits of different policies for protection of threatened species. They illustrate the magnitude of market and non-market benefits and cost that would arise from policies that protect species and show that costs would be concentrated in the areas of commercial fishing while the benefits distribution would be largely outside of this region and vary by state. Boxall et al. (2012) find a similar outcome in the context of Canadian species at risk policy options. A re-focusing of ESV analysis onto distributional questions could be highly valuable in terms of informing public policy.

- d. Indigenous Local Ecological Knowledge (ILEK) and traditional use of resources:
There is increasing awareness of the uniqueness of knowledge and management institutions of indigenous peoples. In the case of NOAA this indigenous knowledge is associated with fish and coastal resources. These topics, while relevant nation-wide, are particularly relevant in the Arctic. There have been relatively few cases of ecosystem service valuation that have focused on Indigenous Peoples and the impact that changes in environmental quality or policy have on well-being. While the theory employed in ESV in such contexts would not differ from traditional analysis, the context would be quite different from traditional ESV analysis of “recreation” or property value analysis. Given that Indigenous People can be heavily reliant on ecosystem services, changes in ecosystem services may affect many aspects of their livelihoods. They may not be as active in the market economy and, thus, valuation exercises may have to employ more data intensive approaches for identifying trade-offs and monetary values. Early work in this area attempted to use the value of substitutes for harvest (e.g., purchased salmon as a replacement for inability to fish for wild salmon using traditional practices) as the value of impacts on ecosystem services. But that approach is flawed as it does not capture the full value of the activity associated with the harvest (e.g., Jackson et al., 2014). A more sophisticated analysis of trade-offs and behavior is required (see Adamowicz et al., 2004).

Discussion of ILEK in resource management often focuses on the potential role of ILEK in monitoring ecosystems and identifying trends in species abundance or presence. But ILEK also provides insights into the impacts of environmental changes on Indigenous peoples and their livelihoods. Viewed in this way the collection and interpretation of ILEK can help facilitate valuation. Measurement of the economic impact on Indigenous Peoples is often lacking in benefit cost or regulatory impact assessment.

- e. Ecosystem Services and values in fisheries beyond “harvest”:
The most common internal application of ESV in NOAA is the analysis of impacts on fish harvest and value. These are monetary values that are relatively easy to obtain and they

comprise a very important component of economic value. However, there is also the possibility of incorporating species interactions (forage fish complexes), habitat and other components of ecosystems into more comprehensive models of ecology and economics. Ecosystem Based Fisheries Management (EBFM) models, Integrated Ecosystem Assessment (IEA) models and Coastal Marine Spatial Planning (CMSP) frameworks are expected to formalize these ecosystem relationships, but these methods often do not integrate the human behavioral / economic elements. Collie et al. (2013) state that while CMSP process often strive to construct decision tools that provide information on trade-offs, such processes seldom do so. Incorporating economic valuation information, through linkages with market based fisheries, or non-market valuation tools, would provide important policy information. Decision support tools such as Marine InVEST are an attempt to move in this direction, but there is still room for improvement in this area.

Areas of Tension

Several challenges arise in the development and application of ESV to decision making areas within NOAA. These tensions often remain unstated (although some are widely recognized), and directly influence the extent to which ESV can be implemented as an ongoing and organic part of NOAA's mission.

Capacity

NOAA lacks ESV expertise in many areas. Expertise is unevenly distributed across the agency. This is a well-established issue with social science more broadly. There are relatively few individuals within NOAA who actively conduct primary research on ESV, and there is relatively little interaction between individuals working in this area across agency line offices. Some areas in NOAA also lack the demonstrated capacity to evaluate the accuracy and validity of ESV approaches used by others (and in the literature), leading to the concern that ESV will be outsourced to unqualified entities and/or those using substandard methods. Some new groups are emerging within NOAA which suggests that interest in the issues is increasing within the organization. There are also concerns regarding funding for research. However, there are also opportunities for synergies between groups. Expertise in the area of NRDA, for example, could be very useful in the evaluation of restoration options or policy / regulatory changes that may arise. If ESV is to be applied more broadly across NOAA, there is a need to establish a higher minimum bar of capacity across the agency—either via added capacity or enhanced sharing/leveraging of existing capacity across offices.

Validity

One of the key factors limiting the use of ESV in decision making and analysis is a set of concerns over validity of the methods. There are both actual and perceived concerns about validity. Within the profession there are concerns about the validity of some approaches to ESV and applications in some contexts, but there is also a rapidly emerging literature outlining conditions for validity. There are also uneven and often misinformed perceptions surrounding the validity of different ESV methods (particularly stated preference methods and certain types of benefit transfers). There can be pressure to avoid “big numbers” that ESV may generate (regardless of method), because analyses often focus on

public rather than private goods. In the case of public goods it is possible for a large number of people to have values associated with a change in ecosystem service and the additive nature of these values can lead to sizable value estimates. Lack of guidance for different methods exacerbates this challenge.

Perceptions of the accuracy, validity and applicability of different methods vary in different ways from the perspectives of the scientific literature. For example, the skepticism over stated preference methods within some areas of NOAA does not appear to match the widespread acceptance of these methods across the scientific literature on ESV, although the quality of stated preference applications in the literature varies. A relatively balanced perspective on the strengths and weaknesses of these methods is provided by Kling et al. (2012). There is an effort underway at this time (Johnston et al. 2015) that is developing a set of contemporary guidelines for stated preference methods. This effort should help provide information on validity and reliability for these methods. In contrast, revealed preference methods are often viewed as being more valid and reliable as they are based on actual behavior. But even in these contexts there are concerns about the lack of data, the challenges in modelling choices and specifying models, and implications of the often strong assumptions that may be required. These issues are well-recognized in the literature (Bockstael and McConnell, 2010).

At the same time, there is a common lack of recognition across the agency of the risks involved in off-the-shelf decision support tools that often rely on some of the least accurate and defensible means of ESV, and of the significant differences in performance associated with different approaches to benefit transfer for ESV (Johnston and Wainger, 2015). Given the often central role of benefit transfer for federal agency ESV, NOAA would benefit from a broader understanding of these methods. Johnston et al. (2015b) provide a comprehensive guidebook to the use of benefit transfer for environmental and resource values.

There are validity issues surrounding all methods, but the understanding of these actual challenges is limited across the agency. There is a need to establish guidelines and realistic expectations regarding the validity of different methods, including stated and revealed preference methods. There is also a need for enhanced recognition of the linkages between (1) the types of values to be estimated, (2) the degree of precision required, and (3) the types of methods that are applicable. Kline and Mazzotta (2012) discuss similar issues within the context of USDA Forest Service decisions. Broad guidance is also provided by the National Ecosystem Services Partnership's (2014) "Federal Resource Management and Ecosystem Services Guidebook" (<https://nespguidebook.com/>), which provides guidance on many of the issues discussed in this report.

Application

There are tensions within the agency regarding the relevance or applicability of valuation, and benefit cost analysis, to several of the agency mandates. The use of economic analysis in the assessment of endangered species is a case in point. While economic analysis is not allowed to play a role in listing, there are concerns about the use of economic analysis for other aspects of endangered species actions, including the application in the Klamath case. If benefit cost analysis is ruled out in some contexts, then clearly so is valuation. But even in cases that allow economic analysis (such as critical habitat determination) it appears that economic analysis and valuation are not often employed (see Plantinga et al., 2014). Activities within NOAA regarding valuation of attributes of protected resource programs clearly fall into this area and most economists would argue that there are benefits of using ESV information in such cases. However, there are different views within the agency regarding the applicability of benefit cost analysis to mandates. On the other hand, there is also concern regarding the

“unequal” inclusion of market values and often exclusion of non-market values. The case of fish-stock rebuilding or fisheries programs in general and their focus on market values, without capturing relevant non-market values (such as recreation) appears to be present. That is, there appears to be inconsistency regarding the treatment of different types of values in different contexts.

Lack of correspondence to agency needs

In many cases there is a lack of correspondence between agency decision-making needs and the information provided by ESV. Primary examples include:

- Decision-making needs that (e.g., due to statute or regulation) provide an unclear (or no) role for ESV to influence decisions.
- Spatial scales that are incompatible with meaningful ESV (e.g., are too small or large for ESV to be calculated with any degree of precision). In the case of NRDA, for example, determination of compensation for damages is often done using resource or habitat based measures without measuring monetary values. The cost of determining monetary values at very small spatial scales, if even possible, would be large and certainly outweigh the value of the information.
- Temporal scales (time periods during which decisions are made) and available resources may be incompatible with the time and resources required to conduct high quality (or any) ESV, particularly when methods require OMB review.
- There is still inconsistent understanding of methods and meaning, and how ESV can help people do their job better. Individuals may not understand where ESV “plugs in” for them. Until this is addressed (how ESV helps people do their jobs better, rather than being another conceptual framework), there will be hesitance to adopt ESV more broadly.
- The design and method of ESV must align with the policy questions. The policy or decision making group should have the ESVs best associated with the questions being asked and the options being considered.
- The methods necessary to estimate relevant ecosystem service values may be those for which (1) there is little capacity within NOAA, (2) there are perceived concerns with validity that may or may not coincide with perspectives of the scientific literature, (3) temporal, resource or process concerns may prevent application.
- Even when ESV *is* relevant to decisions, there may be a lack of understanding of *how and why* it is relevant, particularly among those unfamiliar with economic methods for policy analysis. This may be particularly true for non-market values, which some non-economists may not recognize as being legitimate economic values.

Conclusions / Recommendations: What Should NOAA Do?

There is significant opportunity for ESV to inform and enhance decision-making within NOAA, and to better quantify and communicate the value of the agency's actions to the public. At the same time, broader implementation of ESV as an organic aspect of agency decisions faces constraints related to such factors as lack of capacity and perceived/actual lack of correspondence between agency decision-making needs and the information provided by ESV. There are also uneven and often misinformed perceptions surrounding the validity of different valuation methods. To address these constraints and promote the application of ESV effectively in decision support across the agency's mandates and areas of responsibility, we make the following recommendations. These are purposefully made at a high level, as developing the operational details of such changes will require coordinated efforts across NOAA.

1. NOAA should develop formal written recommendations and guidance linking particular types and applications of ESV to particular types of agency needs. This guidance should also specify cases in which ESV is not recommended for widespread application in the absence of extenuating circumstances. This guidance should reflect the specific contexts within which decisions are made, how information can and should be used to inform these decisions, and whether external constraints (e.g., statutory mandates) explicitly require, prohibit or constrain use of the resulting information to inform decisions. The goal of these recommendations should be to standardize expectations for ESV across different areas of NOAA, and (where applicable) to encourage the use of ESV as an organic component of the agency's decision-making processes. These recommendations should emphasize that it is not feasible to "do ESV everywhere," and instead target clear areas where investments in ESV would produce maximum benefits in terms of agency decisions.
 - a. These recommendations and guidelines should reflect established standards regarding what type of insight can be provided by different types of ecosystem service information. For example, under what conditions is sufficient information provided by simple quantification of ecosystem services (or evaluation of production possibility frontiers), compared to instances in which full ESV is required to provide needed information? See, for example, guidelines for federal agencies provided by Olander et al. (2015), and reflected in the updated Federal Resource Management and Ecosystem Services Guidebook (National Ecosystem Services Partnership, 2014).
 - b. Particular emphasis in methodological guidance and familiarity should be directed at areas and approaches for which common perceptions within NOAA may not correspond with recommended or consensus practices in the scientific literature, or for may lead to misinformed decisions. Examples include ESV using black box or off-the-shelf decision support tools, and methods that do not reflect accepted approaches for economic welfare analysis, as well as the strengths and weaknesses of the alternative methods for benefit transfer.
 - c. Guidance for ESV should clearly distinguish measures that may be interpreted as appropriate measures of economic value, versus other common economic or monetary

measures (e.g., jobs, economic impacts) that do not reflect economic values. Although this is standard practice for benefit cost analysis and is reflected in some current agency documents, understanding of these distinctions is not widespread across NOAA.

- d. These guidelines and recommendation should emphasize the need for direct involvement of natural science and economic experts from the outset of all ESV, to ensure that integrated methods are applied from initial scoping through data collection and analysis.
2. NOAA should develop cross-LO institutions and structures capable of promoting and informing the use of high-quality ESV across the agency. One possible idea for such a crosscutting structure (although not the only one) could be derived from a model such as the National Center for Environmental Economics at EPA. The goal of such institutions and structures would be a strong and active community of practice within NOAA for economic analysis, from which expertise and capacity for ESV could be disseminated and leveraged across the agency. Currently, capacity for ESV within NOAA is concentrated in a few “hot spots,” with other areas largely devoid of capacity. More effective structures for sharing and leveraging capacity would help NOAA maximize its capacity for effective ESV within existing resource constraints. These structures would also help promote ESV as a more organic part of NOAA’s activities, replacing the current focus on scattered, one-off analyses. NOAA’s Chief Economist can play a significant role in this initiative, linking economic analysis across the agency. The location of the Chief Economist in the CFO office of DOC may also be beneficial in developing further linkages, but the unique nature of ESV within economics will require a focus on developing capacity within relevant units in NOAA.
3. In addition to formal guidelines and recommendations noted in Recommendation #1, NOAA should promulgate information and encourage broad institutional learning about intra-agency familiarity with (a) value of information provided by ESV within decision contexts encountered by the agency, and (b) strengths, weaknesses, applicability and validity of different approaches to ESV, as reflected by consensus in the scientific literature. These activities should be coordinated with the guidance described in Recommendation #1 and the community of practice described in Recommendation #2. This information could also be provided via various mechanisms, including workshops, information sessions, online tutorials, and other mechanisms.
4. NOAA should identify a small set of key capacity enhancements that would lead to maximum benefits for the agency’s ability to conduct ongoing ESV as an organic aspect of decision-making. Limitations in NOAA’s capacity in social sciences and some other areas relevant to ESV are longstanding and well-established. Current resource constraints suggest that these broader capacity issues are unlikely to be fully resolved in the near future. Given this situation, the agency should seek to identify realistic goals for capacity enhancements necessary to reach a “minimum bar” of acceptable ESV across the agency. Ideally, these would be enhancements that

address needs across the agency. NOAA should also explore budget neutral options such as coordinating efforts across lines and/or leveraging existing programs and staff.

5. NOAA should engage in meaningful dialogue with OMB (and other agencies, as appropriate) regarding expectations, approvals and constraints for ESV. Among the goals for such dialogue would be to discuss means to enable more efficient and effective approval processes for key ESV methods, and steps that NOAA might take to enable ESV to occur within relevant time and resource constraints. Discussions such as these can also help develop understanding of how/when different approaches will be permitted.
6. All of the above recommendations should be conducted in close coordination with outside ESV communities of practice across different fields, engaging outside experts to ensure that NOAA's ESV activities are consistent with best practice.

While this review had been conducted over a 2-year period, the ESMWG is aware that NOAA is working on its Ecosystem Services Strategy but the group has not yet seen this document. The ESMWG is willing to continue to work with NOAA on ESV issues in the future as the NOAA strategy evolves.

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Appendix 1. Terms of Reference for ESMWG Task Force on Ecosystem Service Valuation

NOAA has requested the Ecosystem Sciences and Management Working Group to review its use of ecosystem service valuation in order to assure it is using the most appropriate methods and applying them effectively in decision support across the agency's many mandates and areas of responsibility. This Terms of Reference (ToR) lays out the initial response to NOAA on how the ESMWG proposes to address the tasks.

There is considerable discussion of ecosystem services and their value in NOAA strategic and planning documents. The recently released National Oceans Policy Implementation Plan states, for example, under the Science and Information section, that an action for 2014 will be to "Identify and collaborate with an ongoing project to employ public input and use socioeconomic and natural sciences to identify, develop, and apply valuation frameworks for ecosystem services." (National Oceans Policy Implementation Plan Appendix, 2013, Page 27). The Next Generation Strategic Plan states "To achieve this objective, NOAA will expand and maintain a reliable and accessible suite of climate, weather, ocean, marine ecosystem, and living marine resource and geospatial information, to improve the understanding of key environmental processes—including occurrence and effect of high impact events— and build capacity in the social, behavioral, and economic sciences to support the valuation of ecosystem services, risk and vulnerability assessments, and decision-support services." (NGSP, Page 25).

In some contexts ecosystem service valuation (ESV) is viewed as a mechanism for decision-making in terms of planning or evaluating of programs or "investments" (e.g., restoration). In other instances ESV is used as a descriptive tool to communicate societal benefit of resources or actions. The focus of the ESMWG in this instance is the use of ESV in decision-making of all types within NOAA. Despite increasingly common use of the terminology, several questions remain regarding the implementation of an ecosystem service valuation framework, the capacity within the agency to employ such a framework (including data, personnel, and research knowledge) and the best way to move forward in building capacity and implementing the approach. In addition, ecosystem service valuation appears in at least four distinct ways within NOAA including Natural Resource Damage Assessment (NRDA), Marine Spatial Planning (MSP), fisheries management, and policy and program evaluation (of programs within the Restore Act for example). Additionally, ecosystem service valuation is being employed by other federal agencies (e.g., US Environmental Protection Agency, USDA Forest Service), and these agencies have been developing their own guidelines and frameworks for the use of ecosystem service valuation in agency decision making (e.g., US EPA SAB, 2009). The linkage and integration of knowledge, data and capacity between these areas and agencies may be particularly beneficial.

In response to the interest in ESV and the challenges in its employment in decision making, the ESMWG (or a sub-committee with support from the overall working group) will produce a document that assesses the questions listed below, in the context of ecosystem services and their contribution to well-being. These questions were developed by the ESMWG and representatives from NOAA, and provide advice regarding the use of an ecosystem services valuation framework. In this process the ESMWG will consider ecosystem service valuation in the context of how it can be used to improve decision making within planning, conservation investments, or other aspects of the agency's mission. The use of an ecosystem service valuation framework to fully assess the benefits and costs of decisions or plans, as well as the distribution of benefits and costs across groups will be considered. The committee will employ the concepts and scope of ecosystem service valuation as outlined in the recent literature (e.g., US EPA SAB, 2009) and focus on recommendations that can be made to improve the use of ecosystem service valuation in agency decisions and processes, and evaluate opportunities for both intra-agency and inter-agency synergy on the use of ecosystem service valuation. Particular attention will be given practical issues related to the Agency's extant capacity for ESV compared to that required for different types of ESV, including those envisioned by the Agency's planning documents. The document will also address the Agency's need for accuracy and quantification in different types of ESV applications and implications for the types of methods that might be applied. In this way, the ESMWG will evaluate the relationship between NOAA's ESV needs (actual or aspirational) in different mission areas and the practical capacity of the Agency to obtain this information.

Key Questions to be addressed (arising from the April 2014 ESMWG meeting):

- 1 A number of different valuation methods and value estimates are available, with varying accuracy, reliability (perceived and actual), and applicability. Required data and expertise also vary across the application of these methods. Given NOAA's capacity for ESV, what guidance can be given regarding the application of methods to specific decision making contexts, and how can the variation in the methods be incorporated into management advice? What is the Agency's current capacity to conduct ESV of the type needed to meet Agency goals, and how does this relate to current government frameworks for incorporating ESV in decision making (e.g., OMB guidance)? What is being done systematically to incorporate ESV into decision making about ecosystem management, and how can it be used to its fullest extent?
- 2 What approaches and criteria can be used by the Agency to determine how and when ecosystem service values should be monetized (i.e., expressed in monetary terms)? What approaches can be most effectively used by NOAA to account for the value of ecosystem services that are difficult to monetize (which includes cultural services and some regulatory services, etc.) and should there be an effort to express value for these services in a different way? How can NOAA do a better job of incorporating the value of these services in policies and decision-making?
- 3 What are the most pressing needs for ecological data and models to support ESV? The ecological data and models needed to carry out these valuations is a critical area that is often considered a road block in using ESV. ESMWG can help identify what is currently and potentially possible through identifying priority gaps, recommending cost-effective approaches to collect baseline ecological data, evaluating levels of uncertainty associated with the use of particular tools, etc.

4 Connectivity – What is the appropriate scale and proximities for undertaking ESV for various habitat types and functional linkages (e.g., value of habitats)? This information would be used to empower local/regional conservation efforts and to enrich the basic principles ESV design. Approach:

The ESMWG task force will address the questions above by examining categories of decisions within which ecosystem service values are used. These decision making categories will help place the ESV tasks in context and will help the ESMWG assess the use of ESV in relation to the decision- making frameworks common to NOAA.

The following types of decisions where NOAA may use ESVs will be examined through the lens of a set of examples of these types of decisions:

-Fishery regulations

-Habitat restoration investment

-NRDA

-Protected area analysis

-Green infrastructure protection / enhancement decisions

-Coastal Zone Management

The ESMWG will examine the following issues as a way to provide a context for addressing the questions above.

1. *What is being done (in terms of ESV information to support decision making, etc.) for the key types of decisions? Which are viewed as “successful”?*
2. *Where are the uncertainties and data gaps largest?*
3. *What are the capacities and gaps in applying ESV to NOAA’s decision making needs?*
4. *What are short term and long term activities that can be implemented to reduce uncertainty / improve decision making, etc.?*
 - o *Data?*
 - o *Models?*
 - o *Framework?*

5. *What internal or external elements limit NOAA in achieving successful ESV?*

References:

United States Environmental Protection Agency Science Advisory Board. 2009. Valuing the Protection of Ecological Systems and Services, A Report of the EPA Science Advisory Board. EPA SAB-09-012.

[http://yosemite.epa.gov/sab/sabproduct.nsf/F3DB1F5C6EF90EE1852575C500589157/\\$File/EP-A-SAB-09-012-unsigned.pdf](http://yosemite.epa.gov/sab/sabproduct.nsf/F3DB1F5C6EF90EE1852575C500589157/$File/EP-A-SAB-09-012-unsigned.pdf)

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Appendix 2. Questions Asked in Survey of NOAA ESV Experts

Questions

- (1) What areas of your work within NOAA enable or require the use of Ecosystem Service Valuation (ESV)? An example would be regulatory or environmental impact statements for which you (or others with whom you work) commonly include information on ecosystem service values.
- (2) How is ESV used to inform decisions in these areas, and how important is ESV to the decisions that are ultimately made?
- (3) What types of methods are used for ESV in these areas? What are the main advantages and limitations of these methods?
- (4) What primary areas of your work within NOAA do not include ESV in any meaningful way, or effectively preclude ESV? An example would be the fish stock rebuilding provisions of Magnuson-Stevens and the National Standards, which require stocks to be rebuilt in 10 years if biologically feasible, regardless of implications for ecosystem service values.
- (5) In your opinion, could ESV be used more effectively in your or other areas of NOAA? Please explain.
- (6) What are the primary limitations to more effective use of ESV within NOAA?