BIOINDICATOR-BASED METHOD FOR VALUING MARINE ECOSYSTEM SERVICES

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EXECUTIVE SUMMARY

Introduction

The proposed creation of marine reserves at Redfish Rocks in Port Orford, Oregon, and at Otter Rock near Newport, Otter Rock, and Depoe Bay, Oregon, creates an opportunity to develop and test a framework for identifying, estimating, monitoring and evaluating the nonmarket costs and benefits of marine reserves in Oregon. The goal of this analysis is to derive candidate indicators of long-term ecological change related to the creation of marine reserves to serve as a starting point for survey development for assessing trade-offs associated with the nonmarket benefits resulting from the creation of marine reserves. These survey indicators will integrate ecological models with the knowledge and preferences of stakeholders in order to allow the use of easily understandable indicators within survey scenarios (the economic component), while providing ecological linkages among these indicators and the assessment endpoints that determine values (the ecological component). The goal of this process is to allow a value to be placed on ecological measurements that in themselves may seem obscure to the stakeholders—and therefore would not be appropriately valued —through their bundling and translation into indicators that have value-related meaning.

This report describes the gathering and synthesis of ecological and socioeconomic data required to translate bioindicators into survey indicators, which represent nonmarket benefits in the form of ecosystem services. Ecosystem services can be defined as “aspects of ecosystems utilized (actively or passively) to produce human well-being” (Fisher et al. 2009, p. 645). Ecosystem services of coastal systems include (Beaumont et al. 2007; Millennium Ecosystem Assessment 2005): *provisioning services*, which are the direct products obtained from the ecosystem such as fish taken for food; *regulating services*, such as the role that extensive kelp beds can play in preventing shoreline erosion; *cultural services*, which provide nonmaterial benefits to humans, such as the identity a community and its population have as a fishing community or a center for whale watching and; *supporting services*, which are necessary for the production of other ecosystem services, but do not directly benefit humans, such as the habitat structure provided by a rocky reef.

The methods used include the use of community focus groups and expert opinion. Community focus groups were organized in each study community (i.e., Port Orford and Newport/Depoe Bay), and two meetings were scheduled with each group. The expert opinion of researchers at Oregon State University and the Oregon Department of Fish and Wildlife helped consolidate ecosystem services identified by stakeholders into survey indicators that are appropriate for a stated-preference context.

Technical details regarding this project and its outcomes are provided in the main body of this report. It is important to measure baseline conditions of proposed marine reserves in particular, and the marine environment in general, in order to evaluate and track changes in ecological conditions, ecosystem services, and social welfare over time. Therefore, monitoring plans should carefully consider the many benefits and costs of changes to the marine environment.

Results

Table ES 1 presents the full set of ecosystem services that participants of the focus groups expect to receive as a result of the implementation of the marine reserves. Provisioning services were the most readily and clearly identified by participants of the first meeting of the Redfish Rocks and Otter Rock focus groups. Provisioning services include those below that begin with “Provision of,” with the exception of *Provision of cultural identity*, *Provision of a culturally-valued seascape*, *Provision of cognitive value*, and *Provision of existence/conservation value*. Most of the provisioning services describe the supply of resources utilized directly or off-site and can be described as the delivery of an ecosystem good. Regulating services identified by participants include those beginning with "Environmental control of" in the list below. Cultural services include *Provision of cultural identity*, *Provision of a culturally-valued seascape*, *Provision of cognitive value*, and *Provision of existence/conservation value.* Participants identified a strong cultural identity with the Oregon coastal environment. Participants' described this identity, however, as being irreducible and not directly attributable to any natural features or qualities over others, a characteristic that poses an analytical difficulty that is discussed in detail in this report and has great bearing on our recommendations below. Supporting services were not identified in this analysis because they do not meet the operational definition of an ecosystem service provided to focus group participants (see Chapter 3) and are therefore unfit for stated-preference valuation. Further explanation is provided in the detailed descriptions of ecosystem services provided in Appendix A.

Table ES 1. Ecosystem services identified during the first meeting of the focus groups

Ecosystem Services
Provision of non-harvested fish
Provision of harvested fish
Provision of non-harvested invertebrates
Provision of harvested invertebrates
Environmental control of harvested invertebrate populations
Provision of non-harvested plants and algae
Environmental control of harvested plant and alga populations
Provision of marine mammals
Provision of sea birds
Provision of geologically mediated habitat and beach
Provision of cognitive value
Provision of cultural identity
Provision of a socially-valued seascape
Provision of water and waves
Environmental control of water quality
Environmental control of air quality
Environmental control of species richness
Environmental control of ecosystem resilience
Environmental control of overall ecosystem condition

Table ES 2 presents the final set of survey indicators resulting from this analysis. The ecosystem services above were consolidated into survey indicators that are appropriate within a stated-preference context. The detailed methodology applied to these analysis is described in Chapter 3.

Table ES 2. Survey indicators developed by consolidating ecosystem services and testing in focus groups

Survey Indicators
The quality of ocean water for purposes of human contact and consumption of seafood
The number of non-harvested fish
The number of harvested fish
The number of non-harvested shellfish
The number of harvested shellfish
The number of non-harvested plants and algae
The number of harvested plants and algae

Survey Indicators
The number of marine mammals
The number of sea birds
A natural and wild Oregon seascape to view and take in
An Oregon ocean that provides personal and scientific discovery
A community identity defined by a connection with the ocean
The resilience of the local fish and shellfish stock
The variety of plants, animals, and habitats
The protection and natural integrity of the marine ecosystem

The final list of survey indicators presented in this analysis is as a starting point for the development and implementation of indicator-based valuation models and strategies for long-term ecological and social monitoring. Toward these ends, we offer the following recommendations:

1. In order to implement a monitoring plan, Oregon Department of Fish and Wildlife should consider prioritizing the candidate list of survey indicators and their associated metrics. One goal of an indicator-based valuation model is to derive weights of relative importance across survey indicators for citizens of Oregon. These preference weights can aid in prioritizing efforts to monitor biological and socioeconomic change resulting from the establishment of marine reserves in Oregon; however, these citizen weights should be balanced with administrators' and scientists' priorities in monitoring ecological and ecosystem services benefits and costs to society.

2. It is recommended that the Oregon Department of Fish and Wildlife reconcile the final survey indicators with available data and current and needed metrics for both socioeconomic and biological monitoring efforts. This process could involve refinement of survey indicators themselves, as well as bioindicators corresponding to each survey indicator.

3. The current list of survey indicators and their linkages to biological information is complex. It is therefore recommended that the Oregon Department of Fish and Wildlife support further work to refine the final survey indicators by evaluating correlations among the final survey indicators and associated bioindicators. This refinement will serve two purposes. First, it will capture important socioeconomic and biological signals from the changes resulting from the establishment of the marine reserves. Second, it will identify potential for indexing survey indicators through a scaling function that captures underlying correlations among various metrics associated with indicators.

4. The list of final indicators presented here is only representative of the sampled population, and is therefore not necessarily exhaustive or generalizable to other populations. It is therefore recommended that the Oregon Department of Fish and Wildlife assess the potential for expanding the list of welfare-relevant ecosystem services and survey indicators. This list could be expanded using benefit transfer techniques, or by repeating this analysis with randomly sampled populations from other communities of place. It is recommended that the Oregon Department of Fish and Wildlife interpret the final list of survey indicators presented in this analysis as reflecting only the input of a sample population of participants that have a very intimate relationship with their local marine environment. Furthermore, the study marine reserves were recognized by some participants as being sited and sized so as to not have significant biophysical effects. As a result, much of the focus group discussion focused on cultural services, which were significant to participants and are analyzed in detail in this report. Any attempt to generalize the final list of survey indicators presented in this analysis should therefore involve additional testing in other communities with a randomized sample of participants, and should address future planned marine reserves with different expected biophysical effects.

5. It is recommended that, when possible, the Oregon Department of Fish and Wildlife favor the selection of bioindicators that measure the composition and structure of the marine community over those that measure specific populations of species. The results of the focus groups suggest that participants are neither concerned with nor expecting an increase in any species of organism in particular. Furthermore, a focus on community-level bioindicators will facilitate synergy in measurement of multiple survey indicators.

6. Outcomes from the stakeholder focus groups identified dimensions important to them beyond biological and ecosystem services indicators. These survey indicators include holistic views by participants with regards to the marine environment and their perceptions of broader relationships among them, such as: *A natural Oregon seascape to view and take in*, *An Oregon ocean that provides personal and scientific discovery*, and *A community identity defined by a connection with the ocean*. We recommend that Oregon Department of Fish and Wildlife be cognizant of these broader social dimensions and implement appropriate metrics to monitor them over time. Specifically, these indicators are devised to accommodate the difficulty participants had extricating their conceptualization of the local marine environment according to specific assessment endpoints. These indicators above are therefore neither intended to be broken down into distinct ecosystem services, nor be structurally linked to bioindicators. This outcome has a few implications. First, further research is warranted to better define the utility functions underlying these indicators. The proceedings of the first meeting of the focus groups suggested that, while it is possible that ecosystem services contribute to stakeholders' conceptualization of these indicators, it is likely that other psychological and social metrics—such as values and attitudes—contribute in kind. Second, if these final survey indicators are used as presented in this analysis, they should be measured using social and economic metrics.

7. It is recommended that the Oregon Department of Fish and Wildlife conduct further research into defining and measuring uncertainty associated with marine reserves. The indicator *The resilience of the local fish and shellfish stock* is designed to incorporate uncertainty into the full set of survey indicators. Participants expressed concerns during the focus group meetings regarding the unknown future value of environmental assets. In the case of this survey indicator, it is utilized for its contribution to a more certain estimation of future food and resource scarcity values. The type of value that this indicator captures is called *option value*—a type of nonuse value—which can be seen as the difference between valuation under conditions of certainty and uncertainty. Furthermore, one of the tenets of ecosystem-based management is the *precautionary principle*, which stresses a preference for using conservation measures like marine reserves to manage for uncertainty.

8. It is recommended that the Oregon Department of Fish and Wildlife conduct further research into defining and measuring *existence value*—another type of nonuse value—associated with marine reserves. The indicator *The protection and natural integrity of the marine ecosystem* captures this value by referring to the degree to which the marine ecosystem is perceived of as operating in a natural state. Participants of both focus groups expressed strong values for the overall condition of their local marine environment, even if that condition did not change the output of other ecosystem services. Stakeholder values related to biodiversity should also be explored within this same context, rather than with regard for its potential productive value.

CHAPTER 1 – BACKGROUND AND INTRODUCTION

BACKGROUND

In March of 2008, Oregon Governor Kulongoski signed Executive Order 08-07 calling for the recommendation of less than ten sites for the creation of marine reserves in state coastal waters (State of Oregon 2008). Marine reserves are spatially defined areas of the ocean or coastal waters within which all extractive practices are prohibited for the purpose of protecting specific marine resources from direct human impact. Within marine reserves in Oregon, extractive practices are defined as “fishing, hunting and harvesting of shellfish, other invertebrates, kelp and seaweed.” In addition, new ocean developments requiring state authorization (e.g. wave energy and aquaculture) are also prohibited within marine reserves. All other non-extractive activities not having “a negative impact on marine habitats and biodiversity protected within the site” are allowed (State of Oregon 2008). As of this year, two marine reserves have been approved for implementation. These two marine reserves are currently in a *pilot* phase to allow for the collection of baseline ecological and socioeconomic information. The pilot marine reserves and adjacent communities serve as the study sites for this analysis.

The first study site is the community of Port Orford, Oregon, adjacent to which a 2.6 mile marine reserve was established at Redfish Rocks. Bordering the Redfish Rocks marine reserve is a 5 square mile marine protected area extending seaward within which bottom-disturbing fishing gear is prohibited, but authorized salmon and crab fishing is allowed. The second study site includes the communities of Newport, Otter Rock, and Depoe Bay, Oregon, adjacent to which a 1.3 mile marine reserve was established at Otter Rock. The Otter Rock marine reserve is not buffered by a marine protected area. Four other sites in Oregon are currently being considered for future marine reserves. Marine reserves in Oregon have three stipulated goals: to conserve marine habitats and biodiversity; provide a framework for scientific research and effectiveness monitoring; and avoid significant adverse social and economic impacts on ocean users and coastal communities (State of Oregon 2008).

The creation of the two pilot marine reserves provides an opportunity to develop and test a framework for identifying, estimating, monitoring and evaluating the nonmarket costs and benefits of marine reserves.

INTRODUCTION

Research Problem

A full baseline socioeconomic study requires describing initial conditions using data and other measurements, possibly including estimating nonmarket costs and benefits associated with implementation of the marine reserves, as well as a method for tracking long-term change to these metrics. Existing research on marine reserve effectiveness, however, focuses on developing sets of management indicators tied to outcomes listed in a marine reserve management plan or on the achievement of a single objective such as an increase in the size or number of female fish in the marine reserve (see Bernstein et al. 2004). These approaches fail to capture the dynamic complexity of social, cultural, economic and ecological processes and the trade-offs associated with the establishment of marine reserves.

Ecosystem-Based Management

There is a need for new approaches to evaluate the efficacy of marine reserves that are grounded in the emerging ecosystem-based management paradigm. The goal of ecosystem-based management is to conserve, maintain and restore ecosystem functions to promote the economic and ecological sustainability of marine ecosystems and human communities, both coastal and more broadly, that depend on the services they provide (McLeod et al. 2005; Levin and Lubchenco 2008). Nevertheless, ecosystem-based management advocates that common social values and preferences be considered within a scientific understanding of the ecosystem (Crowder and Norse 2008).

Ecosystem Services

Key to integrating the biophysical and human dimensions of ecosystem-based management is the concept of ecosystem services (Fisher et al. 2008, 2009; Crowder and Norse 2008; Millennium Ecosystem Assessment 2005; NRC 2005). Ecosystem services can be defined as “aspects of ecosystems utilized (actively or passively) to produce human well-being” (Fisher et al. 2009, p. 645). Ecosystem services of coastal systems include (Beaumont et al. 2007; Millennium Ecosystem Assessment 2005): provisioning services that are the direct products obtained from the ecosystem such as fish taken for food; regulating services, such as the role that extensive kelp beds can play in preventing shoreline erosion; cultural services providing nonmaterial benefits to humans, such as the identity a community and its population have as a fishing community or a center for whale watching and; supporting services that are necessary for the production of other ecosystem services, but do not directly benefit humans, such as the habitat structure provided by a rocky reef.

While research on marine ecosystem services is an emerging area of study with limited existing studies, employing ecosystem services in marine spatial planning policies such as the creation of marine reserves is of national concern. Final recommendations from the White House Council on Environmental Quality’s Interagency Ocean Policy Task Force’s protecting the ability of resilient ecosystems to deliver ecosystem services as one of their seven national goals (WHCEQ 2010). The Ocean Policy Task Force also relates ecosystem services to marine spatial planning by further recommending coastal and marine spatial planning as a policy tool suited to the preservation and enhancement of ecosystem services.

Bioindicators

To bring these general tenets from idealism to pragmatism, measurable indicators must be identified, evaluated, and monitored over time. Turnhout et al. (2007, p. 217) define an ecological indicator (hereafter *bioindicator*) as “a framework of parameters that indicate the current and/or desired ecological or nature quality of a certain area.” For example, an indicator of aquatic living resources might characterize the health, composition, or diversity of aquatic organisms present in an ecosystem.

Similar indicators can be developed to measure ecosystem services. USEPA (2009) describes the functions of indicators of ecosystem services as used for three purposes: to help communicate the roles of ecosystems to decision makers in an effective manner; to provide the biophysical information necessary for analyzing ecological change in response to policy choices, and; to facilitate valuation studies.

This analysis develops, implements, and tests a method for achieving the third purpose – the facilitation of a valuation study. Specifically this analysis facilitates the valuation of incremental change to the marine environment in Oregon in response to the two study marine reserves through development of a bioindicator-based valuation method that uses marine ecosystem services as indicators for estimating economic use and non-use values and benefits associated with marine resources. This analysis fits within a broader program of study on Oregon’s coastal resources (Harte et al. 2010).

Stated-Preference Valuation

Within stated-preference or survey-based valuation, the role of bioindicators is to communicate changes in resource quality or quantity, such that meaningful expressions of value may be elicited. Such information must not only be placed in a format that is readily understood by respondents, but that also provides an accurate representation of the policy change being valued (Mitchell and Carson 1989; Bateman et al. 2002). As stated by Schiller et al. (2001, p. 3), "effective communication of ecological indicators involve[s] more than simply transforming scientific phrases into easily comprehensible words. [It requires] language that simultaneously fit[s] within both scientists' and nonscientists'...frames of reference, such that resulting indicators [are] at once technically accurate and understandable." Furthermore, the validity of welfare estimates depends on appropriately integrating bioindicators and economic information (Johnston et al. 2002, 2010).

Stated-preference methods are frequently employed to assess use and nonuse values associated with changes in environmental resources (Aas et al. 2000; Bateman and Willis 1999; Bauer et al. 2004; Bennett and Blamey 2001; Collins et al. 2005; Nunes and Blaeij 2005; Teisl et al. 1996; Wessells 2002). Nonetheless, unlike indicators developed within the ecological literature (e.g., Karr 1991; Engle et al. 1994; Summers et al. 1995; Weisberg et al. 1997), indicators used within stated-preference surveys are often based on *ad hoc* metrics unrelated to formal models of ecosystem change. More specifically, measures of change in environmental resources presented in stated-preference surveys: a) are rarely developed within the context of established ecological models; b) rarely address uncertainty associated with prediction and measurement, c) are often ambiguously linked to quantifiable and measurable long-term policy impacts; and d) are often based on arbitrary or vague measurement units. Lack of quantifiable correspondence between changes in environmental resources provided in survey instruments and measurable changes resulting from policy implementation may render benefit estimates of limited relevance, lead to biased welfare estimates, and contribute to misguided policy.

A second feature given little attention in the stated-preference literature is the different ways in which the public understands changes in environmental resources and in which such attributes affect utility. Focus groups reveal that respondents typically view ecosystem changes relative to historical or pristine conditions, or based on a common language understanding of ecosystem health (Schiller et al. 2001). In contrast, common metrics used in stated-preference surveys (e.g., 1 million juvenile fish; 20,000 sea birds) typically have little meaning to respondents. Indeed, with the exception of a few well-known metrics (e.g., the RFF water quality ladder), there has been little attention provided to the development of meaningful (Elbert and Welsch 2004), consistent bioindicators in stated-preference research. The concern is that if survey scenarios provide inaccurate or confusing representations of environmental policy impacts, even the most apparently robust willingness to pay estimates may provide biased welfare information.

These and other limitations of traditional stated-preference valuation approaches have led to increasing calls for survey-based approaches that more closely correspond to ecological ecosystem assessments using bioindicators (Johnston et al. 2010; Kontogianni et al. 2010). This analysis combines stated-preference survey methodology with formal ecological models linking indicators to assessment endpoints from which utility is derived. They are distinguished by a formal basis in established integrative ecological indices, and an associated structure determining what types of indicators are appropriate for communication of specific assessment endpoints.

Research Goal

The goal of this analysis is to derive candidate indicators of long-term ecological change to serve as a starting point for development of a survey instrument for assessing trade-offs associated with the benefits resulting from the creation of marine reserves. These indicators (hereafter referred to as *survey indicators*) will integrate ecological models with the knowledge and preferences of stakeholders in order to allow the use of easily understandable indicators within survey scenarios (the economic component), while providing unambiguous ecological linkages among these indicators and the assessment endpoints that determine values (the ecological component).

Survey indicators must meet the following theoretical requirements:

1. Link attributes of ecological models and ecosystem services (assessment endpoints) that provide utility to respondents
2. Be appropriate for economic valuation in that they are unambiguous and quantitatively commensurate with neoclassical utility models used for valuation
3. Provide information that is meaningful, comprehensive, and comprehensible (do not present excessive cognitive demands) to non-scientist survey respondents

The goal of this process is to allow a value to be placed on ecological measurements that in themselves have little meaning to the average stakeholder, and therefore would not register accurate valuation, through their bundling and translation into indicators that have value-related meaning.

Research Objectives

Objective 1: Identify ecosystem services that influence stakeholders' utility.

Objective 2: Identify previously developed indicators or indices of biophysical change (i.e. bioindicators) related to the creation of marine reserves.

Objective 3: Define structural linkages between bioindicators and welfare-relevant ecosystem services.

Objective 4: Develop and test indicators of ecosystem services for stated-preference valuation.

CHAPTER 2 – ANALYTICAL FRAMEWORK

CONCEPTUAL FRAMEWORK

In order to derive sound valuations of changes in ecosystem services resulting from the creation of marine reserves, ecological metrics must be integrated with metrics of social analysis. The conceptual framework aims to describe a method for structurally linking these two tools through the translation of bioindicators into indicators of ecosystem services.

Supply and Demand

In order to assign social values to ecological endpoints (biophysical characteristics or qualities indicated by bioindicators), the supply of and demand for a particular endpoint must be assessed. The supply of an endpoint is described through a functional relationship called an *ecological production function* and the demand for it is described by a functional relationship called an *economic demand function* (Leslie and McCleod 2009, p. 92). An ecological production function describes the relationship between the natural features of the marine system and the ecological capacity of the system to supply ecological endpoints, which, in the case of this analysis, serve as proxies for ecosystem services. An economic demand function relates characteristics of the stakeholder to the value they place on ecosystem services.

This analysis informs both of these functional relationships. Specifically, Objectives 1 and 2 limit the scope of the ecological production function by identifying welfare-relevant ecosystem services and those ecological endpoints that can proxy for welfare-relevant ecosystem services. Objectives 3 and 4 then define bundles of ecosystem services that can be translated into survey indicators for input into the related economic demand function.

Demand-side characteristics (e.g. substitutability) depict the benefits of the ecosystem services. Fisher (2008) notes that marginal supply and demand are where policy and economic decisions operate. Benefits of ecosystem services are assessed through analysis of the relationship between supply and demand, which is made clear via biological (supply) and economic (demand) monitoring of changes in survey indicators and corresponding bioindicators over time. In order for demand to be assessed empirically, however, survey indicators must represent the final goods or services being demanded by users. It is therefore important that survey indicators presented in this analysis are understood by both natural scientists and stakeholders to mean the same thing. Furthermore, this understanding allows ecological monitoring efforts and socioeconomic monitoring efforts to remain separate, which in turn allows knowledge and theoretical foundations developed in ecology and economics to be properly coordinated. This analysis therefore treats the analysis of supply and the analysis of demand separately.

Ecological Production Function

In order to identify ecosystem services that influence respondents' utility (Objective 1), ecosystem services must first be properly defined. Ecosystem services have been defined for many purposes, including as a heuristic tool (Costanza 1997; deGroot 2002; MA 2005). This definition is widely criticized, however, for not being operational for purposes of environmental valuation and decision-making (Boyd and Banzhaf 2006; USEPA 2009; Fisher et al. 2008; Fisher et al. 2009; Wallace 2007; Hein 2006). To address this problem, economists conceptualize ecosystem services in the context of ecological production functions. The features in these constructs that individuals utilize (*assessment endpoints*) are the outputs of the ecological system, called *final ecosystem services*. In contrast, other features of the ecosystem may combine to produce these outputs and are thus called *intermediate ecosystem services*.

Biologists and ecologists, however, conceptualize the marine ecosystem according to *ecological endpoints*, rather than assessment endpoints. Bioindicators used in biological monitoring (Objective 2) therefore can correspond to either final or intermediate ecosystem services and are measurement endpoints, or ecological measures that are used within formal frameworks to communicate, infer, or predict changes in assessment endpoints (USEPA 1998). Importantly, however, only final ecosystem services are valued in the economic demand function. The value of intermediate services are captured in the value of final ecosystem services, and therefore are not valued individually because aggregation would lead to double counting. As a consequence, only those bioindicators that correspond to final ecosystem services should be monitored as part of the ecological production function. Through this process, final ecosystem services and bioindicators are structurally linked (Objective 3).

While an understanding of the relationship of intermediate services to final services is important to understanding, assessing, predicting and managing final ecosystem services and associated benefits (USEPA 2009), a complete understanding of this process is quite difficult and involves a range of uncertainties, including spatial and temporal nonlinearities (Barbier et al. 2008). This is an ongoing area of ecosystem services research that falls mainly within the disciplines of ecology, biology, and biogeochemistry, and is not attempted in this analysis.

Rather, this project aims to consolidate final ecosystem services into survey indicators that are appropriate within a stated-preference context. Consolidation of final ecosystem services requires a qualitative analysis of basic functional relationships between ecosystem services and, by extension, to corresponding bioindicators. Such an analysis facilitates the identification of potential synergies or trade-offs between ecosystem services, which should be reflected in either their consolidation into a survey indicator or separation into different survey indicators. Furthermore, identifying potential for synergies and trade-offs informs the process of balancing the benefits of *differentiation* versus *undifferentiation* in the phrasing of the indicators, a topic that is discussed in the following sections. Two types of functional relationships are considered in this analysis.

The first type of functional relationship considered is the productive relationships between final ecosystem services. The distinction between final and intermediate services depends on the benefit in question. It is therefore possible for the same ecological endpoint to be both a final and intermediate service. For example, clean water may be an ecological endpoint for a swimmer who wants to avoid contact with pollution. To a fisherman, however, clean water may combine with physical habitat to serve as intermediate services into the endpoint of crab abundance. In this case, the endpoints of water quality and crab abundance should be separated into two survey indicators to avoid double counting.

The second type of functional relationship considered is the interaction between final ecosystem services. Types of interactions among ecosystem services include positive or negative, unidirectional or bidirectional, and opposite or same direction (Bennett et al. 2009). Avoiding the consolidation of ecosystem services that interact or respond to drivers in opposite ways will help avoid complications in measurement.

Defining the point at which an ecological endpoint enters into an individual's utility function is a complicated task. This task can be facilitated by consideration of how an individual benefits from the endpoint and what type of value that benefit satisfies. It is widely argued that, in order to relate and evaluate ecological complexities related to the provision of ecosystem services, classification systems should distinguish between ecosystem services and social benefits (Fisher 2008; Fisher 2009; Wallace 2007; Hein 2006; Boyd and Banzhaf 2006) in addition to distinguishing between intermediate and final ecosystem services. The grouping of ecosystem services can therefore be facilitated by considering the type of benefit they provide and the type of value that benefit satisfies. One useful tool is the total economic value (TEV) framework (Morton 1999), which includes direct and indirect use values and nonuse values (i.e., option, existence and bequest values).

Economic Demand Function

In order to be appropriate for a demand analysis, survey indicators must at once represent the final ecosystem services being demanded by users, as well as meet certain theoretical criteria specific to stated-preference methods (Objective 4), which are described in the previous chapter. Ensuring an indicator represents the final ecosystem services being demanded by users is a procedural question described in more detail in the next chapter.

OPERATIONAL FRAMEWORK

The operational framework describes a method for gathering the ecological and socioeconomic data required to translate bioindicators into survey indicators. This method involves the use of community focus groups and expert opinion.

Community focus groups were used to complete Objective 1 and part of Objective 4 of this analysis. Specifically, a focus group was organized in each study community (i.e., Port Orford and Newport/Depoe Bay), and two meetings were scheduled with each group. The method of sampling the participant population is described in the following chapter. The first meeting was designed to address Objective 1 by allowing local stakeholders of each marine reserve to describe the range of benefits and final ecosystem services they receive from their local marine environment, as well as estimate how those metrics might change as a result of their local marine reserve. The resulting data serve three purposes. First, they tailor the scope of the ecological production function by defining a set of metrics that are relevant to the welfare of stakeholders. Second, they detail the utility functions of stakeholders, which informs the process of consolidating final ecosystem services into survey indicators (Objective 3). Third, they provide valuable qualitative insight into the values, goals, and criteria of the study population. This information informs the development of the language used to present the survey indicators (Objective 4).

The second meeting of the focus groups was designed to further address Objective 4 by testing the survey indicators for their ability to clearly represent the final ecosystem services demanded by stakeholders in the first community focus groups, as well as meet certain theoretical criteria specific to stated-preference methods. In addition, the second meeting included questions designed to identify ecological features or qualities that stakeholders associated with change to each indicator. Resulting data further refines the subset of bioindicators that can be linked to each survey indicator (Objective 3).

The expert opinion of researchers at Oregon State University was used to complete Objective 3. As noted in the previous section, final ecosystem services resulting from the first meeting of the focus groups were consolidated into survey indicators that are appropriate within a stated-preference context. This process included a qualitative analysis of two types of basic functional relationships between final ecosystem services, which apply to corresponding bioindicators, as well. Corresponding indicators were identified (Objective 2) by conducting a literature review and the input of scientists at Oregon State University and the Oregon Department of Fish and Wildlife. The detailed methodology applied to these analysis is described in the following section.

CHAPTER 3 – METHODOLOGY

IDENTIFYING ECOSYSTEM SERVICES

This section describes the methods used to complete Objective 1 (Identify ecosystem services that influence respondents' utility) and results of the first meeting of the Redfish Rocks and Otter Rock focus groups.

Development of Definitions and Questions

Questions developed for the first meeting of the focus groups were aimed at generating, in order, three types of data: baseline socioeconomic and cultural benefits generated by participants' "local marine environment"; related baseline final ecosystem services; and expected marginal changes in both benefits and final ecosystem services resulting from the creation of their respective marine reserve.

The definitions of an ecosystem service and a benefit should make clear that one produces the other, and that benefits are directly responsible for human welfare. Without this connection, participants may identify ecosystem services that are not welfare-relevant, or conversely, participants may identify benefits that are not directly provided by ecosystem services.

In order to meet this requirement, the following operational definition of a benefit was adapted from Fisher (2008):

> *"Something that has a direct impact on your (human) welfare."*

Next, the following operational definition of an ecosystem service was adapted from USEPA (2009):

> *"An aspect of the natural environment that directly provides or produces a benefit."*[1]

Last, questions were designed to estimate the marginal changes in both benefits and final ecosystem services. These questions began with the scenario of introducing a marine reserve to a community's baseline local marine environment and estimating the resulting change to the baseline benefits and ecosystem services.

The First Meeting of the Focus Groups

Staff at the Oregon Department of Fish and Wildlife assisted in recruiting the participant population in each study community. Participants were contacted based on meeting one or all of the following criteria: 1) they were known to be active in the ocean planning process in their community, 2) that they are or were a member of one of the community teams developed during the marine reserves process and are associated with the stakeholder categories stipulated in Oregon House Bill 3013: local government, recreational fishing industry, commercial fishing industry, nonfishing industry, recreationalists, conservation, coastal watershed councils, relevant marine and avian scientists, or 3) were a member of one of the recognized communities of place and associated with one of the stakeholder categories listed in Oregon HB 3013. This sampling method was not intended to generate a representative population. Rather, participants were recruited with the goal of further engaging active stakeholders.

[1] This definition describes what is referred to above as a "final" ecosystem service, although this distinction was not made to participants of the focus group for the sake of simplicity.

The first meeting of the Redfish Rocks focus group was held at the City Hall in Port Orford, Oregon, at 6:00pm on June 1, 2010. Ten participants attended, representing six stakeholder groups. The first meeting of the Otter Rock focus group was held at the Guin Library on the Hatfield Marine Science Center campus in Newport, Oregon, at 3:00pm on June 10, 2011. Twelve participants attended, representing six stakeholder groups.

The first meeting of the focus group began by providing participants the definition and examples of a benefit and an ecosystem service. Once the definition was clear, participants were asked to first identify benefits that they received from their local marine environment. Second, they were asked to identify those ecosystem services that directly provided those benefits. Lastly, participants were asked to estimate if their local marine reserve would change the provision of those benefits and ecosystem services ("increase, decrease, no change, or unsure").

Results

The first focus groups resulted in three categories of data. The first category is a list of benefits and related ecosystem services provisioned to participants from their local marine environment. This data was gathered in response to structured questioning. The second category is an estimation of expected changes to this flow of benefits and ecosystem services resulting the establishment of the marine reserves, also gathered in response to structured questioning. The third category is a record of general language describing participants' values, goals, and criteria related to their local marine environment and marine reserve. Much of this language was peripheral to the guided discussion but nonetheless valuable to the process of phrasing indicators.

These three types of data were synthesized in order to generate the final list of benefits and related ecosystem services. Table 3.1 provides the full list of benefits and related ecosystem services flowing to stakeholders from the study marine environments, and estimated change to this flow resulting from the study marine reserves.

Table 3.1. Benefits and ecosystem services flowing to stakeholders from the study marine environments and expected changes to each as a result of the study marine reserves.

Benefits	Change	Ecosystem Services	Change
Physical activity	(+)	Provision of non-harvested fish	(?)
Human health: avoidance of pollution	(0)	Provision of harvested fish	(?)
Psychological and emotional health	(+/-)	Environmental control of harvested fish populations	(?)
Viewing of scenery	(+)	Provision of non-harvested invertebrates	(?)
Viewing of wildlife	(+)	Provision of harvested invertebrates	(?)
Using the beach	(+)	Environmental control of harvested invertebrate populations	(?)
Marketing and consumption of seafood	(0)	Provision of non-harvested plants and algae	(0)
Catching fish and invertebrates	(-)	Provision of harvested plants and algae	(0)
Harvesting plants and algae	(-)	Environmental control of harvested plant and alga populations	(?)
Food security and sustainability	(+)	Provision of marine mammals	(+)
Cultural identity	(+)	Provision of sea birds	(+)
Ecological knowledge	(+)	Provision of geologically mediated habitat and beaches	(0)
Opportunity for stewardship and conservation	(+)	Provision of cognitive value	(+)
		Provision of cultural identity	(+)
		Provision of a socially-valued seascape	(+)

Benefits	Change	Ecosystem Services	Change
		Provision of water and waves	(0)
		Environmental control of water quality	(0)[1]
		Environmental control of air quality	(0)
		Environmental control of species richness	(+)
		Environmental control of ecosystem integrity and resilience	(+)
		Environmental control of overall ecosystem condition	(+)

Notes:
(+) Denotes an increase
(-) Denotes a decrease
(+/-) Denotes stakeholder group-specific change
(0) Denotes no change
(?) Denotes uncertainty in direction of change
1. Participants noted that while they do not expect provision of this ecosystem service to change as a result of their marine reserves, they thought it possible it could improve as a result of additional marine reserves.

The benefits listed in Table 3.1 conform to the same strict definitions given to participants of the first two focus groups. Many benefits listed were explicitly identified by participants in response to prompting. Other benefits listed, however, were generated by the researchers *ex-post* through an interpretive process. It should be noted that participants identified benefits in order to identify and compartmentalize related ecosystem services. Benefits are presented in this section with the same purpose, rather than as an endpoint of the analysis.

Ecosystem Services

Similarly, the final list of ecosystem services conforms to the same strict definitions given to participants of the first meeting of the focus groups. This section classifies the ecosystem services identified from the first meeting of the focus groups according to four categories defined in the Millennium Ecosystem Assessment (2005): provisioning services, regulating services, cultural services, and supporting services.

Provisioning services were the most readily and clearly identified by participants of the first meeting of the Redfish Rocks and Otter Rock focus groups. Provisioning services include all those in Table 3.1 that begin with “Provision of,” with the exception of *Provision of cultural identity*, *Provision of a culturally-valued seascape*, *Provision of cognitive value*, and *Provision of existence/conservation value*. Most of the provisioning services describe the supply of resources utilized directly or off-site and can be described as the delivery of an ecosystem good. Many provisioning ecosystem services may appear either redundant or generalized, which is the outcome of an effort to generate a parsimonious list that also reflects the utility functions of participants. For example, *Provision of fish* and *Provision of harvested fish* are two distinct ecosystem services referring to mutually-exclusive sets of species because of the differing substitutability between different species of fish across the utility functions of fishermen and nonconsumptive observers of fish. Specifically, commercial fishermen only target or are permitted to target specific species, while the recreational diver is not limited to viewing only a subset of fish species. Further explanation is provided in the detailed descriptions of ecosystem services provided in Appendix A.

Regulating services identified by participants include those beginning with “Environmental control of” in Table 3.1. Regulating services are distinct from provisioning services in that, in addition to the quantity of an environmental feature, they imply a criteria for the delivery of the service. For example, the service *Environmental control of harvested fish populations* partially provides the benefit of *Marketing and consumption of seafood* because participants expressed a preference for the sustainability of the product, and sustainability of seafood is delivered over a different time scale than the provision of the fish at any given moment.

An analytical difficulty arises with the description of cultural and ecologically indistinct services. Participants identified a strong yet irreducible identity with the culture of the Oregon coast. Participants' descriptions of this feeling were often nebulous, romanticized, and not directly attributable to any natural features or qualities over others. Given the limitations of this analysis, therefore, an exclusive ecosystem service was generated to encompass this vague cultural element: *Provision of cultural identity*. Two other cultural ecosystem services were similarly devised to describe the delivery of a singular benefit or value: *Provision of cognitive value* and *Provision of existence/conservation value*. In addition, a fourth ecosystem service, *Provision of a socially-valued seascape*, was devised to deliver part of the benefit of *Viewing of scenery*. Participants identified a number of discrete ecosystem services as contributing to the scenery their local marine environment, such as the provision of kelp visible on the surface of the water, the sea air, waves, and rocks and reefs. Stakeholders also noted, however, that the aesthetic of the seascape is provisioned by the interaction of all the natural features. This less discrete element is represented in the ecosystem service, *Provision of a socially-valued seascape*.

These four services, however, are not commensurate with provisioning and regulating services because they do not describe the delivery of discrete biophysical features and qualities and therefore cannot be unambiguously linked to bioindicators. Furthermore, many provisioning and regulating ecosystem services are intermediate to these four ecosystem services. With regard to valuation, therefore, aggregation of these services with provisioning and regulating services could lead to double counting issues or biased welfare estimates. As a result, these ecosystem services each constitute its own indicator, a topic discussed in more detail in the following chapter.

Supporting services were not identified in this analysis because they do not meet the operational definition of an ecosystem service provided to focus group participants (see the Millennium Ecosystem Assessment 2005) and are therefore unfit for stated-preference valuation (Rudd et al. 2007).

IDENTIFYING BIOINDICATORS

This section describes the methods used to complete Objective 2 (Identify previously developed indicators or indices of biophysical change related to the creation of the marine reserves).

Use of Academic Literature and Expert Opinion

Previously developed bioindicators were identified from academic literature (Hakanson and Bleckner 2008; Methratta and Link 2006; Pelletier et al. 2008; Pomeroy et al. 2004; Rice 2003; Rochet and Trenkel 2003) and the knowledge of participating scientists from Oregon State University[2] and the Oregon Department of Fish and Wildlife[3].

This list of indicators was modified to eliminate redundancy and account for feasibility given current research efforts, as well as categorized the list according to major components of an ecosystem. The modified list is presented in Appendix B. It should be noted, however, that this list is larger than the subset demanded by stakeholders, which is presented in the following chapter.

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[2] Including Dr. Selina Heppell and Dr. Sarah Henkel in the Department of Fisheries and Wildlife.

[3] Including Alix Laferrier.

DEFINING STRUCTURAL LINKAGES

This section describes the methods used to complete Objective 3 (define structural linkages between indicators and welfare-relevant ecosystem services).

Final Ecosystem Services and Final Indicators

Only final ecosystem services are valued in the economic demand function. The value of intermediate services are captured in value of final services, and therefore are not valued individually because aggregation would lead to double counting. As a consequence, only those bioindicators that correspond to final ecosystem services are monitored as part of the ecological production function. Final ecosystem services were related to bioindicators by researchers at Oregon State University. Table 3.2 presents these relationships.

Table 3.2. Bioindicators by ecosystem service

Ecosystem Service	Biophysical Indicator
Provision of non-harvested fish	Extracted organism density[1]
	Fish presence[1]
	Fish abundance[1]
	Fish density[1]
Provision of harvested fish	Extracted organism individual size[1]
	Trophic level of landings[5]
	CPUE per species[6]
Environmental control of harvested fish populations	Extracted organism biomass[5]
	Extracted organism individual size[1]
	Mean individual fish length[4]
	Mean individual fish weight[4]
	Rockfish length distribution[2]
	Rockfish age distribution[3]
	Post-settlement juvenile abundance[2]
Provision of non-harvested invertebrates	Extracted organism density[1]
	Benthic cover[6]
	Invertebrate presence[1]
	Invertebrate relative abundance[1]
	Invertebrate abundance[1]
	Invertebrate density[1]
Environmental control of harvested invertebrate populations	Extracted organism biomass[6]
	Extracted organism individual size[1]
Provision of non-harvested plants and algae	Benthic cover[6]
	Bull Kelp percent cover (subsurface)[1]
	Bull Kelp biomass[1]
	Understory kelps and algal presence[1]
	Understory kelps and algal percent cover[1]
	Understory kelps and algal density[1]
	Bull Kelp percent cover (surface)[1]
Provision of harvested plants and algae	Bull Kelp percent cover (subsurface)[1]
	Bull Kelp biomass[1]
	Understory kelps and algal presence[1]

Ecosystem Service	Biophysical Indicator
	Understory kelps and algal percent cover[1]
	Understory kelps and algal density[1]
Environmental control of harvested plant and alga populations	
Provision of marine mammals	N/A
Provision of seabirds	N/A
Provision of geologically mediated habitats and beach	Habitat distribution[3]
	Habitat complexity[3]
Provision of cognitive value	N/A
Provision of cultural identity	N/A
Provision of a socially-valued seascape	Bull Kelp percent cover (surface)[1]
Provision of water and waves	N/A
Environmental control of water quality	Light/turbidity[3]
	Density of suspended toxins[3]
	Density of suspended bacteria[3]
Environmental control of air quality	N/A
Environmental control of species richness	Relative species abundance[3]
	% Predatory fish[5]
	Species richness/diversity index[3]
	Habitat complexity[3]
	Biotic habitat diversity[3]
	Invertebrate relative abundance[1]
Environmental control of ecosystem resilience	Trophic level of landings[5]
	Food web integrity[3] Habitat integrity[3] Recruitment success within the marine reserve[3]
Provision of existence/conservation value	Area showing signs of recovery[3]
	Area under no or reduced human impact[3]

Sources:
1. Alix Laferrier, Oregon Department of Fish and Wildlife
2. Selina Heppell, Oregon State University
3. Pomeroy et al. 2004
4. Methratta and Link 2006
5. www.indiseas.org
6. Petellier et al. 2009

Functional Relationships

A qualitative analysis of the basic functional relationships between final ecosystem services was conducted in order to identify potential for synergy or trade-offs between ecosystem services, as well as avoid complications in measurement.

The first type of functional relationship analyzed is the productive relationships between final ecosystem services (Boyd and Banzhaf 2006). Since it is possible for the same ecological endpoint to be both a final and intermediate service, some final ecosystem services identified in the first meeting of the focus groups serve as inputs into the production of others. In these cases, the two ecosystem services should not be aggregated into a single indicator in order to avoid potential double counting issues. The second type of functional relationship is the interaction between final ecosystem services, which can reveal that, alternatively, some ecosystem services may negatively affect the production of others (Bennett et al. 2009). In these cases, change in the two ecosystem services should not be aggregated into a single indicator, but rather be presented as a trade-off, since an increase in one comes at the decrease of another.

It should be noted that many interactions between final ecosystem services reflect basic, general trophic interactions. The degree to which these interactions can be refined and qualified is limited only by the complexity of the marine ecosystem in Oregon and our knowledge of it. A first-order analysis, however, is appropriate for this analysis.

Appendix C presents a matrix of these functional relationships between final ecosystem services identified during the first meeting of the focus groups. Ecosystem services down the left column are analyzed for their interaction with ecosystem services across the top row of the matrix. Instances of one ecosystem service serving as an input into the production of another are denoted with blue boxes containing a + symbol; negative inputs are denoted with orange boxes containing a - symbol; and context- or stakeholder-dependent interactions are denoted with yellow boxes containing a +/- symbol. Ideally, the aggregation of ecosystem services should be avoided if they interact in a positive (productive), negative, or context-dependent way (i.e., they are connected by a symbol in the matrix). Although the strength of these relationships should be considered as well (Bennett et al. 2009). For example, *Provision of plants and algae* contributes productively to *Environmental control of water quality*. Aggregating these two ecosystem services into one indicator (e.g. *The provision of plants and algae* and *Environmental control of water quality*) may cause a respondent who is aware of this interaction to value plants and algae twice (Kontogianni et al. 2010): once for their provision of aesthetics, and again for their contribution to the regulation of water quality. Alternatively, *Provision of plants and algae* should be separated from *Provision of harvested invertebrates*, since an increase in purple urchins may lead to an increase in predation on kelp beds, and thus a trade-off exists. Aggregating these ecosystem services into one indicator may elicit a biased welfare estimate from a respondent who is aware of these natural interactions. Furthermore, the measurement of corresponding bioindicators may be complicated by similar interactions. For example, measurement of changes in the abundance of fish should not be conducted with community-level indicators, since changes to the ecosystem services *Provision of harvested fish* and *Provision of non-harvested fish* may move in different directions due to food-web interactions.

DEVELOPING SURVEY INDICATORS

This section describes the method used to complete Objective 4 (develop and test indicators of ecosystem services for stated-preference valuation).

The principal challenge in the development of survey indicators is the consolidation or reduction of ecosystem services into a smaller number of metrics or descriptive attributes suitable for survey use. It is critical that in transforming ecosystem services into simpler forms, the underlying information is not overly diluted, such that descriptions remain consistent and meaningful, and resulting survey indicators remain unambiguously linked to the underlying bioindicators. At the same time, indicators must communicate information that is meaningful, comprehensive, and comprehensible to non-scientist respondents.

Correspondence to Bioindicators and Ecological Models

The requirement that indicators correspond to ecological models is addressed in two steps, both described in the previous section. In summary, however, the ecosystem services identified in the first focus groups are structurally linked to bioindicators identified through a review of academic literature and correspondence with scientists at Oregon State University and the Oregon Department of Fish and Wildlife.

Phrasing of Indicators and Economic Valuation

After determining the constituent ecosystem services to be presented in each indicator, the language used to present the indicator was developed through two processes. The first process was the initial phrasing of the indicators, which was conducted by researchers at Oregon State University. The second process was confirmation and editing by stakeholders in the second meeting of the focus groups. The two main challenges to finding the appropriate phrasing of indicators are determining what information to include and determining the degree to which that information is disaggregated.

Types of information

The first focus group provided not only information on valued ecosystem services, but also on related benefits and expected changes, as well as a wealth of descriptive language regarding the values, goals, criteria, and points of view of the participants. Phrasing of each indicator began with the ecosystem services it was designed to include. Benefits were included in the language of a number of indicators in order to elucidate the connection between the ecosystem service(s) presented and respondents' welfare. References to additional language were included sparingly, and only in cases where researchers believed it was desirable for the context of ecosystem service provision to resonate with respondents.

Differentiation

Information gathered from the first two focus groups also revealed details about the values of participants for certain ecosystem services. A central component to the form an indicator takes is the degree to which it differentiates the commodities presented (Boyd and Krupnick 2009). It is necessary therefore to balance the benefits of presenting a undifferentiated commodity (e.g., "The abundance of sea life visible underwater") with the benefits of presenting differentiated commodities (e.g., "The abundance of fish" "the abundance of marine mammals," etc.) is needed. In general, researchers favored differentiation for four reasons. First, differentiation provides more information about the commodity. Second, differentiation allows for more direct correspondence to bioindicators. Third, differentiation facilitates the communication of context-dependent commodities (i.e., the incorporation of benefits and other information). Fourth, differentiation facilitates the avoidance of "expansive priors" (unstated assumptions). Presentation of undifferentiated commodities, however, does have the benefit of putting the commodity in question within a particular context or associating it with another commodity. Researchers therefore developed undifferentiated commodities in instances where information from the previous focus groups indicated that respondents were valuing "compound endpoints," and thus combining commodities was important to their utility.

Additional considerations

Researchers also considered three additional principles for developing survey indicators. First, indicators had to represent biophysical features, quantities or qualities that require little further translation to make clear their relevance to human well-being. Second, the list must be exhaustive and non-duplicative while providing for parsimony by keeping a focus on substantive or material services. Third, regulation alone (i.e. the creation of the marine reserve) does not create a final ecosystem good or service (USEPA 2009).

Results

The following list of fourteen indicators resulted from this stage of the analysis and were presented for testing to participants of the second meeting of the focus groups[4].

1. The quality of ocean water for purposes of human use
2. The quality of ocean water for purposes of fish, plant, and animal use
3. The condition of beaches as places to enjoy
4. The abundance of all types of fish
5. The abundance of all types of shellfish
6. The abundance of kelp, seaweed, and algae
7. The abundance of birds and marine mammals
8. The availability of fish and shellfish to catch, eat, and market locally
9. A natural and wild Oregon seascape to view and take in
10. An active and dynamic Oregon ocean to discover, study, and learn from
11. Community identity through connectedness with the ocean
12. The diversity of plants, animals, and habitat
13. Knowing that the marine ecosystem is functioning more naturally overall

TESTING SURVEY INDICATORS

These fourteen survey indicators were then tested for suitability for the second meeting of the focus groups, the process for which is described in this section.

Development of the Questions

Questions developed for the second meeting of the focus groups were aimed at generating, in order, four types of data for each indicator.

The first type of data is a measure of understandability *prima facie* of the phrasing of the indicator. This measure is necessary to meet the criteria for the presentation of indicators within a stated-preference context. Questions include:

- Does this indicator make sense as it is worded now?
- Is there another way to say this that is more clear?
- Would you be able to respond to this, or is it confusing?

The second type of data is a set of features included in respondents' understanding of the indicator. This set of features confirms that participants understand the survey indicator to refer to the same ecosystem services as scientists understand them to. Questions include:

- What comes to mind when you read this indicator?
- What features of the environment are included in this indicator?
- What would this indicator look like if it increased or decreased?

The third type of data is a set of measurements for monitoring change in each indicator over time. These measurements inform the selection of corresponding bioindicators. Questions include:

- How would you notice this indicator changing over time?
- Has this indicator changed in the past ten years?

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[4] The Redfish Rocks group received a list with language describing change to the state of the indicator, such as "increased" or "maintained." This language was uniformly considered to complicate the indicator description, and was therefore removed from the list provided to the Otter Rock group.

The fourth type of data is a measure of detail necessary to present in each indicator. This measure informs the question of differentiability discussed above. Questions include:

- Are any of these indicators similar enough that they can be combined?
- Is there too much information in this indicator? Should it be split into two separate indicators?

Second Meeting of the Focus Groups

The second meeting of the Redfish Rocks focus group was held at the Port Orford public library at 6:00pm on June 16, 2011. Five of the original ten participants attended, representing three stakeholder groups. The second meeting of the Otter Rock focus group was held at the Guin Library on the Hatfield Marine Science Center campus at 3:00pm on June 20, 2011. Nine of the original twelve participants attended, representing six stakeholder groups.

The second meeting of the focus groups involved presenting fourteen indicators, one by one, to participants. For each indicator presented, moderators asked participants questions designed to elicit the four types of data listed above (i.e., a measure of understandability *prima facie* of the phrasing of the indicator, a set of features included in respondents' understanding of the indicator, a set of measurements for monitoring change in each indicator over time, and a measure of detail necessary to present in each indicator). The lists of indicators presented to each group were the same with regard to content, although the phrasing of the list presented to the Newport group was slightly modified to incorporate feedback from the Port Orford group.

Final Survey Indicators

This section presents the list of final survey indicators and maps each indicator to constituent ecosystem services (Table 3.3). This section also describes the process of incorporating the results of the second meeting of the focus groups into the development of the final survey indicators.

Table 3.3. Final survey indicators and constituent ecosystem services

Survey Indicator	Ecosystem Service
The quality of ocean water for purposes of human contact and consumption of seafood	Environmental control of water quality
The number of non-harvested fish	Provision of non-harvested fish
The number of harvested fish	Provision of harvested fish
The number of non-harvested shellfish	Provision of non-harvested invertebrates
The number of harvested shellfish	Provision of harvested invertebrates
The number of non-harvested plants and algae	Provision of non-harvested plants and algae
The number of harvested plants and algae	Provision of harvested plants and algae
The number of marine mammals	Provision of marine mammals
The number of sea birds	Provision of sea birds
A natural and wild Oregon seascape to view and take in	Provision of a socially-valued landscape
An Oregon ocean that provides personal and scientific discovery	Provision of cognitive value
A community identity defined by a connection with the ocean	Provision of cultural identity
The resilience of the local fish and shellfish stock	Environmental control of ecosystem resilience Environmental control of harvested fish populations Environmental control of harvested invertebrate populations Environmental control of harvested plant and alga populations
The variety of plants, animals, and habitats	Environmental control of species richness Provision of geologically mediated habitat and beach

The protection and natural integrity of the marine ecosystem	Environmental control of overall ecosystem condition

Water Quality

This category includes one survey indicator: *The quality of ocean water for purposes of human contact and consumption of seafood.* This indicator includes the ecosystem service, *Environmental control of water quality* (see Table 3.3) and three biophysical indicators (see Table 3.2).

This survey indicator replaces indicators 1 and 2 (see the *Results* section above) from the second meeting of the focus groups. Participants of both focus groups were confused by aspects of indicators 1 and 2. Specifically, while participants agreed that indicator 1 referred to whether the ocean water was safe to come in physical contact with, they were not sure if the phrase “human use” in indicator 1 included consumption of seafood. Similarly, they were not sure if indicator 2 was meant to be “for the fish itself or for humans.”

The final indicator above addresses this confusion by keeping the original environmental description (“quality of water”) and including both benefits to humans (“human contact” and “consumption of seafood”). While this indicator could potentially be differentiated, doing so would likely lead to confusion in participants over the difference between the two. This indicator could be simplified to its environmental description (i.e., “the quality of ocean water”) if it were found that it would not create the same confusion caused by indicators 1 and 2.

Indicator 2 was discarded due to participants’ response that it made them think of the health of ocean life and the ecosystem overall. Furthermore, the ecosystem service associated with this indicator (*Environmental control of water quality*) directly provides two benefits (*Human health: avoidance of pollution* and *Consumption of seafood*).

Abundance of Organisms

This category includes eight survey indicators:

- The number of non-harvested fish
- The number of harvested fish
- The number of non-harvested shellfish
- The number of harvested shellfish
- The number of non-harvested plants and algae
- The number of harvested plants and algae
- The number of marine mammals
- The number of sea birds

This set of survey indicators replaces indicators 4 thru 8 from the second meeting of the focus groups (see the *Results* section above) with two modifications.

The first modification involves the phrasing of the survey indicators. Specifically, the word “number” replaces the word “abundance.” Participants noted that the term “abundance” was ambiguous, and that it could be at once interpreted by the general public as implying a large quantity, and at the same time be interpreted by scientists to meaning a basic count of organisms. Since the phrasing of these survey indicators is not intended to imply a particular quantity of organisms, the word “number” is used for all eight survey indicators in this category. The consistent use of the word “number” also facilitates comparisons between the survey indicators in this set.

The second modification involves a wholesale change to the structure and presentation of the six ‘harvested/non-harvested’ survey indicators (i.e., *The number of harvested fish*, *The number of non-harvested fish*, etc.). Indicators 4 thru 8 presented during the second meeting of the focus groups were structured so that indicators 4 thru 7 represented the abundance of “all types” of organisms and indicator 8 represented harvested organisms. The six ‘harvested/non-harvested’ survey indicators reflect the conversion of indicator 8 into three survey indicators representing harvested fish, shellfish, and plants and algae (as well as the survey indicator, *The resilience of the local fish and shellfish stock*), while converting indicators 4 thru 7 into three indicators representing non-harvested fish, shellfish, and plants and algae. Separating ‘harvested’ and ‘non-harvested’ survey indicators also avoids the potential confusion between indicators that represented “all types” of organisms and one that represented a subset: organisms for harvest (indicator 8).

Indicator 8 was converted because participants of both focus groups had trouble interpreting it due to ambiguous and encumbered language. Specifically, the phrase “to catch, eat, and market locally” elicited thoughts of the economic market for fish, rather than those species that are available for recreational and commercial harvest. This phrase was originally included in response to descriptive language gathered from the first meeting concerning the importance of the economic multiplier effect that seafood has in the local economy. Since the phrase “market locally” proved confusing, however, it is jettisoned from the three ‘harvested’ survey indicators. Furthermore, since the phrase “to catch [and] eat” implies “harvested,” the latter term was used in the corresponding survey indicators. It should be noted, however, that the aspect of sustainability to the fishery is not captured in the ‘abundance’ indicators, but is rather addressed in the survey indicator, *The resilience of the local fish and shellfish stock*.

It would be possible to aggregate the six ‘harvested/non-harvested’ survey indicators into two indicators: one representing all harvested organisms and the other representing all non-harvested organisms. Participants in both focus groups, however, responded well to indicators 4 through 6 in part because they were concise and singular. Furthermore, participants commented that indicator 7 should be divided into two indicators in order to maintain consistency, as well as because some individuals participate in bird watching or whale watching and not the other. All survey indicators in this category are therefore fully differentiated and do not include descriptive language.

Sense of Place, Identity, and Community

This category includes 3 survey indicators:

- A natural and wild Oregon seascape to view and take in
- An Oregon ocean that provides personal and scientific discovery
- A community identity defined by a connection with the ocean

This set of survey indicators represent modifications to indicators 10 and 11 presented during the second meeting of the two focus groups (see the *Results* section above). These three survey indicators each correspond to one ecosystem service, and are discussed in turn.

A natural and wild Oregon seascape to view and take in

This indicator tested well with participants of both focus groups and has not been modified. This survey indicator was originally designed to represent the ecosystem service *Provision of a socially-valued seascape*. This ecosystem service is one of the four categorically distinct ecosystem services that is not directly tied to discrete biophysical features or qualities. This indicator thus relies on language from the first meeting of the focus groups to describe the socially-valued seascape. In addition, it added “to view and take in” in order to limit the indicator description to tangible aesthetics.

Participants noted that the descriptors “natural and wild” painted a clear picture that they identified with and cared about. Participants also noted that the activities “to view and take in” were clear and associated with the rest of the indicator. When participants were prompted to describe how the indicator would be different without the activities (i.e., “A natural and wild Oregon seascape”), they noted that it evoked just an idea, rather than an idea and experience. Since the survey indicator was intended to limit the perception of participants to an environs that they experienced, rather than appreciated for its existence value, it was therefore kept intact and is presented as such in the final list of survey indicators.

An Oregon ocean that provides personal and scientific discovery
This survey indicator replaces indicator 10 (see the *Results* section above) and represents two modifications. Unlike indicator 9 presented during the second meeting of the focus groups, indicator 10 did not test well.

The first modification addresses the descriptors (i.e., “active and dynamic”). This language was originally included in indicator 10 refer to that used by participants of both focus groups to describe the aspects of their local marine environment that they found mysterious and exciting. Participants, however, found the descriptors superfluous and confounding. Since the descriptors are in fact nonessential, this final survey indicator is differentiated to exclude them. The second modification is the inclusion of language that more closely references the ecosystem service this indicator represents (i.e., *Provision of cognitive value*, see Table 3.3).

A community identity defined by a connection with the ocean
This survey indicator replaces indicator 11 (see the *Results* section above) and represents a slight modification in phrasing. Indicator 11 tested well during the second meeting of both focus groups. Participants noted that the meaning and phrasing of the indicator was clear and accurately described their sense of community identity. The phrase “through a connectedness” in indicator 11, however, is replaced with the phrase “defined by a connection” in this survey indicator in response to suggestions from participants of both focus groups.

Community Socioeconomics

This category includes two survey indicators:
- The resilience of the local fish and shellfish stock

This set of survey indicators preserves indicator 12 and replaces indicator 8 presented during the second meeting of the focus groups (see the *Results* section above) with one modification. These survey indicators address important socioeconomic aspects of the two study communities, and are related with regard to the economic base of the community. It should be noted, however, that the values of stakeholders underlying both of these indicators are profoundly important and complex. Future research into developing a complete and nuanced set of survey indicators is therefore warranted.

The resilience of the local fish and shellfish stock
This survey indicator represents two modifications to indicator 8 presented during the second meeting of the focus groups (see the *Results* section above). The first modification is the disassociation of indicator 8 into three survey indicators representing the abundance of harvested organisms, and this survey indicator representing the sustained supply of harvested organisms.

The second modification to indicator 8 is the incorporation of descriptive language from both meetings of both focus groups (see the *Results* section above). Specifically, the word “local,” which was originally included in indicator 8, was preserved in this survey indicator. The value of locally supplied and marketed seafood was extremely important to participants and elicited passionate discussion during the second meeting of the Otter Rock focus group in particular. Also, the descriptive term “resilience” was added to this survey indicator. These terms were not incorporated into indicator 8 or any other indicators presented during the second meeting for the purposes of presenting parsimonious and differentiated indicators. Participants, however, did not interpret indicator 8 to imply a sustainable or resilient supply of seafood. Rather, participants discussed the dynamics of the economic market for seafood with regard to price and without regard to the delivery of seafood through time. It was therefore determined that an additional indicator should be developed in order to represent the important concept of resilience to the fishery.

This survey indicator could potentially be differentiated according to phylum of the harvested organisms (i.e., *The resilience of the local invertebrate stock*, etc.). Further research into the precise utility functions of commercial and recreational fishermen might reveal that a differentiated indicator is appropriate. In addition, differentiation of this indicator would facilitate with the three survey indicators representing the abundance of harvested organisms. This survey indicator is undifferentiated in this analysis, however, because participants of the first meeting of both focus groups did not differentiate when discussing their interested in the resilience and sustainability of their fishery. Rather, participants referred to their fishery as a collective resource. Furthermore, participants of the first meeting of the Redfish Rocks focus group identified the benefit of *Food and resource security*, which represents the option value of a resilient local community of harvested organisms.

The Marine Ecosystem Overall

This category includes two survey indicators:

- The variety of plants, animals, and habitats
- The protection and natural integrity of the marine ecosystem

This set of survey indicators replaces indicators 13 and 14 (see the *Results* section above) presented during the second meeting of both focus groups. These indicators were presented together in order to ensure that they were not interpreted by participants to be functionally related. Specifically, indicator 13 was intended to represent the diversity of sea life between species, rather than genetic diversity within species, functional diversity, or other rubrics used to indicate ecosystem health and resilience.

The variety of plants, animals, and habitats

This survey indicator represents a slight modification in phrasing from indicator 13. Specifically, the term “variety” in the survey indicator replaces the term “diversity” in indicator 13. Participants of both focus groups noted that the term “diversity” resembled the term “biodiversity.” Furthermore, participants noted that the term “variety” painted a visual picture. Since this indicator is intended to represent the ecosystem service, *Environmental control of species richness* in connection with the benefit of *Viewing of wildlife*, the term “variety” is adopted in this survey indicator.

It should be noted that this survey indicator is not differentiated (i.e., three or more indicators, such as *Variety of fish*, *Variety of plants and algae*, etc.) because participants of both focus groups described their vision of diversity as a community-level feature of the ecosystem. For example, participants noted that a motivation for diving is viewing a diverse scene of interacting sea life, and that fishermen are excited by the surprise of pulling up a rare species of organism, regardless of whether it is a fish or invertebrate, for example. This result suggests that the commodity of species diversity enters into the utility functions of participants as a compound endpoint. Furthermore, this result is contrasted with the view of participants that specific activities motivated by the benefit of *Viewing of wildlife* (i.e., bird watching versus whale watching) would correlate with the abundance of the targeted phylum, rather than the diversity between those species in that phylum.

These results also suggest that differentiation would have more potential costs than benefits. One potential cost is that presentation of a trade-off between abundance and diversity on a phylum-level may imply complex ecological concepts. Not only should an indicator or the presentation of an indicator avoid *expansive priors* in general (see the *Differentiation* section for a discussion of this concept), but this indicator in particular is intended to avoid representing complex ecological concepts. Second, focus group participants did not indicate that this commodity is context-dependent, suggesting that differentiation would not improve the clarity of the composite attributes (i.e., plants, animals, and habitats).

The protection and natural integrity of the marine ecosystem
This survey indicator represents a modification of indicator 14 presented during the second meeting of the focus groups (see the *Results* section above). This survey indicator represents the ecosystem service *Environmental control of overall ecosystem condition*. See Appendix A for a discussion of the complexity of this ecosystem service and its related benefit.

Indicator 14 was presented differently than others in the second meeting of the focus groups. Rather than asking participants questions aimed at generating the three types of data described previously, participants' description of their sense of conservation and existence value were explored. First, the concept of conservation and existence value was explained to participants. Participants were then asked if Indicator 14 clearly represented the concept, which it did for most participants of both focus groups. One critical comment from participants of both focus groups, however, was that Indicator 14 described a feature of the ecosystem that serves as an input into the quality or quantity of other ecosystem services presented. This survey indicator, however, is intended to represent the sense of existence value expressed by participants of the first meeting of the focus groups. Specifically, participants discussed the opportunity for stewardship based on the goal of improving the environment for the sake of the environment, rather than for the effect that an improved environmental state has on other services to them. Therefore, more tested is needed to describe the context within which they utilize the protection and natural integrity of the marine environment.

Discussion
Indicator 3 (see the *Results* section above) was removed from the list of final survey indicators presented in this analysis and was not replaced with another indicator that explicitly represents ecosystem services provided exclusively by beaches. Results of the second meeting of the focus groups provided two reasons for this decision. First, participants had difficulty specifying ecosystem services that contribute to the "quality" of a beach as a place to enjoy. Rather, participants noted that the quality of a beach was very subjective and included features such as access and amenities that are not provided by the marine environment. Further testing is therefore warranted to articulate the unique ecosystem services provided exclusively by beaches, as well as the contexts within which they are utilized.

Final Survey Indicators and Biophysical Indicators
This section describes the linkages between final survey indicators and corresponding bioindicators. Bioindicators were selected in order to represent the understanding of both scientists and focus group participants. Indicators in this section therefore are selected from the full list of biophysical indicators presented in Appendix C according to the results of the second meeting of both focus groups—specifically the features of the environment associated with each indicator and the set of measurements for identified for monitoring change in each indicator over time. See Appendix D for a discussion of the results of the second meeting of the focus groups and participants' concept of metrics for measurement of the survey indicators. See the section *Use of Academic Literature and Expert Opinion* for a discussion of the process of selecting biophysical indicators. Table 3.4 below maps final survey indicators to constituent bioindicators.

Table 3.4. Final survey indicators and constituent bioindicators

Survey Indicator	Bioindicator
The quality of ocean water for purposes of human contact and consumption of seafood	Nutrient loading[4] Density of suspended toxins[4] Density of suspended bacteria[4] Abundance of intertidal indicator species (profile per species)[1] Point source pollution[1] Non-point source pollution[1] Mussel Watch[1]
The number of non-harvested fish	Fish abundance (profile per species)[3] Fish presence (profile per species)[3] Fish density (profile per species)[3] Sea bird abundance[1] Sea bird vital rates[1] Sea bird health[1] Sea bird stomach contents[1]
The number of harvested fish	Extracted fish individual size (profile per species)[3] Trophic level of landings[5] Catch per unit effort (CPUE)[6] CPUE per species[6] CPUE variability[6] Fish abundance (profile per species)[3] Fish presence (profile per species)[3] Fish density (profile per species)[3] Sea bird abundance[1] Sea bird vital rates[1] Sea bird health[1] Sea bird stomach contents[1]
The number of non-harvested shellfish	Extracted organism density (profile per species, such as urchins, mussels, clams, and crabs)[3] Benthic cover[6] Invertebrate density (profile per species)[3] Invertebrate presence (profile per species)[3] Sea bird abundance[1] Sea bird vital rates[1] Sea bird health[1] Sea bird stomach contents[1]
The number of harvested shellfish	Extracted invertebrate individual size (profile per species)[3] CPUE[6] CPUE per species[6] CPUE variability[6] Sea bird abundance[1] Sea bird vital rates[1] Sea bird health[1] Sea bird stomach contents[1]
The number of non-harvested plants and algae	Benthic cover[6] Understory kelps and algal presence (profile per species)[3] Understory kelps and algal percent cover (profile per species)[3] Understory kelps and algal density (profile per species)[3]
The number of harvested plants and algae	Bull kelp percent cover (subsurface)[3] Bull kelp percent cover (surface)[3] Bull kelp biomass[3] Understory kelps and algal presence (profile per species)[3] Understory kelps and algal percent cover (profile per species)[3] Understory kelps and algal density (profile per species)[3]
The number of marine mammals	Marine mammal abundance[1] Marine mammal presence[1] Whale watching logs[1]
The number of sea birds	Sea bird abundance[1] Sea bird presence[1]
A natural and wild Oregon seascape to view and take in	Bull kelp percent cover (surface)[3]
An Oregon ocean that provides personal and scientific discovery	None
A community identity defined by a connection with the ocean	None
Community employment and income	None
The resilience of the local fish and shellfish stock	Trophic level of landings[5] Food web integrity[4]

Survey Indicator	Bioindicator
	Recruitment success within the marine reserve (profile per species)[4]
The variety of plants, animals, and habitats	Relative species abundance[4] Percent predatory fish[5] Species richness/diversity index[4] Habitat complexity[4] Biotic habitat diversity[4] Invertebrate relative abundance[3]
The protection and natural integrity of the marine ecosystem	Area showing signs of recovery[4] Area under no or reduced human impact[4] Food web integrity[4]
Sources: 1. Results of the second meeting of the focus groups. 2. Selina Heppell, Oregon State University 3. Alix Laferrier, Oregon Department of Fish and Wildlife 4. Pomeroy et al. 2004 5. http://www.indiseas.org 6. Petellier et al. 2009	

CHAPTER 4 – DISCUSSION

This chapter discusses the results of the analysis in context of its stated goals, as well as the greater policy context of marine reserve creation in Oregon. Included in the discussion are general considerations regarding the outcomes of the analysis and a description of the limitations of the analysis and recommended future research towards the implementation of the final list of survey indicators.

General Considerations

Consideration of this analysis should account foremost for the unique population of stakeholders sampled to participate in the focus groups. As discussed in the previous chapter, participants were sampled based in part on their being active in the ocean planning process in their community. This sampling method had the goal of further engaging active stakeholders, and did not generate a population representative of a broader regional or state-wide community of place. Any attempt to generalize the final list of survey indicators presented in this analysis should therefore involve additional testing in other communities with a randomized sample of participants.

The final list of survey indicators presented in this analysis should therefore be interpreted as reflecting only the input of a sample population of participants that have a very intimate relationship with their local marine environment. In particular, the sample population exhibited an exceptional knowledge of and appreciation for the complexities of their local marine environment. This characteristic complicated the proceeding and outcomes of the first meeting of the focus groups by causing participants to at times lose sight of the definition of ecosystem services provided to them in favor of discussing the holistic nature of their local marine ecosystem.

This tendency, and much of the resulting information, could be seen two ways. First, it could be seen as peripheral to the task at hand during the first meeting of the focus groups, and could be limited in future analyses through a refinement of the definitions presented to participants or the methods used to moderate the focus groups. In particular, more attention could be paid to separating ecosystem dynamics from ecosystem outputs. In this analysis, however, the holistic views of participants are incorporated into the study results—specifically in the ecosystem services, *Provision of a socially-valued landscape*, *Provision of cognitive value*, and *Provision of cultural identity*, as well as the survey indicators, *A natural Oregon seascape to view and take in*, *An Oregon ocean that provides personal and scientific discovery*, and *A community identity defined by a connection with the ocean*. (See Appendix A and the previous chapter for a more detailed discussion of these ecosystem services and final survey indicators, respectively.)

The need to devise these metrics points to the complex and compound utility functions of the sampled participants, as well as to the limits of this analysis. Specifically, these indicators are devised to accommodate the difficulty participants had extricating their conceptualization of the local marine environment according to specific assessment endpoints. These indicators above are therefore neither intended to be broken down into distinct ecosystem services, nor be structurally linked to bioindicators.

This outcome has a few implications. First, further research is warranted to better define the utility functions of underlying these indicators. The proceedings of the first meeting of the focus groups suggested that, while it is possible that ecosystem services contribute to stakeholders' conceptualization of these indicators, it is likely that other psychological and social metrics—such as values and attitudes—contribute in kind. Second, if these final survey indicators are used as presented in this analysis, they should be measured using social and economic metrics.

For example, participants noted that the regulation of the establishment of marine reserves indicated an increase in the survey indicator, *A cultural identity defined by a connection with the ocean*. Furthermore, a change in this indicator would likely be contingent on a range of other responses by community members, such as marketing. Since a regulation alone cannot constitute an ecosystem service, it could not be claimed that this a change in this indicator following the establishment of a marine reserve would be fully attributable to a concurrent change in ecosystem services via a change in the biophysical environment. Rather, social and economic metrics must also be monitored in order to measure this indicator, as well as identify trade-offs between biophysical and social benefits. For example, participants noted that the establishment of the marine reserves might increase visitation on the beach, which would increase trampling of intertidal marine organisms and habitats. This trade-off can only be measured if it is clear which stakeholders identify culturally with visitation versus which identify with the state of the natural environment.

Recommendations

The final list of survey indicators presented in this analysis is as a starting point for the development and implementation of indicator-based valuation models and strategies for long-term ecological and social monitoring. Toward these ends, we offer the following recommendations:

1. In order to implement a monitoring plan, Oregon Department of Fish and Wildlife should consider prioritizing the candidate list of survey indicators and their associated metrics. One goal of an indicator-based valuation model is to derive weights of relative importance across survey indicators for citizens of Oregon. These preference weights can aid in prioritizing efforts to monitor biological and socioeconomic change resulting from the establishment of marine reserves in Oregon; however, these citizen weights should be balanced with administrators' and scientists' priorities in monitoring ecological and ecosystem services benefits and costs to society.

2. It is recommended that the Oregon Department of Fish and Wildlife reconcile the final survey indicators with available data and current and needed metrics for both socioeconomic and biological monitoring efforts. This process could involve refinement of survey indicators themselves, as well as bioindicators corresponding to each survey indicator.

3. The current list of survey indicators and their linkages to biological information is complex. It is therefore recommended that the Oregon Department of Fish and Wildlife support further work to refine the final survey indicators by evaluating correlations among the final survey indicators and associated bioindicators. This refinement will serve two purposes. First, it will capture important socioeconomic and biological signals from the changes resulting from the establishment of the marine reserves. Second, it will identify potential for indexing survey indicators through a scaling function that captures underlying correlations among various metrics associated with indicators.

4. The list of final indicators presented here is only representative of the sampled population, and is therefore not necessarily exhaustive or generalizable to other populations. It is therefore recommended that the Oregon Department of Fish and Wildlife assess the potential for expanding the list of welfare-relevant ecosystem services and survey indicators. This list could be expanded using benefit transfer techniques, or by repeating this analysis with randomly sampled populations from other communities of place. It is recommended that the Oregon Department of Fish and Wildlife interpret the final list of survey indicators presented in this analysis as reflecting only the input of a sample population of participants that have a very intimate relationship with their local marine environment. Furthermore, the study marine reserves were recognized by some participants as being sited and sized so as to not have significant biophysical effects. As a result, much of the focus group discussion focused on cultural services, which were significant to participants and are analyzed in detail in this report. Any attempt to generalize the

final list of survey indicators presented in this analysis should therefore involve additional testing in other communities with a randomized sample of participants, and should address future planned marine reserves with different expected biophysical effects.

5. It is recommended that, when possible, the Oregon Department of Fish and Wildlife favor the selection of bioindicators that measure the composition and structure of the marine community over those that measure specific populations of species. The results of the focus groups suggest that participants are neither concerned with nor expecting an increase in any species of organism in particular. Furthermore, a focus on community-level bioindicators will facilitate synergy in measurement of multiple survey indicators.

6. Outcomes from the stakeholder focus groups identified dimensions important to them beyond biological and ecosystem services indicators. These survey indicators include holistic views by participants with regards to the marine environment and their perceptions of broader relationships among them, such as: *A natural Oregon seascape to view and take in*, *An Oregon ocean that provides personal and scientific discovery*, and *A community identity defined by a connection with the ocean*. We recommend that Oregon Department of Fish and Wildlife be cognizant of these broader social dimensions and implement appropriate metrics to monitor them over time. Specifically, these indicators are devised to accommodate the difficulty participants had extricating their conceptualization of the local marine environment according to specific assessment endpoints. These indicators above are therefore neither intended to be broken down into distinct ecosystem services, nor be structurally linked to bioindicators. This outcome has a few implications. First, further research is warranted to better define the utility functions underlying these indicators. The proceedings of the first meeting of the focus groups suggested that, while it is possible that ecosystem services contribute to stakeholders' conceptualization of these indicators, it is likely that other psychological and social metrics—such as values and attitudes—contribute in kind. Second, if these final survey indicators are used as presented in this analysis, they should be measured using social and economic metrics.

7. It is recommended that the Oregon Department of Fish and Wildlife conduct further research into defining and measuring uncertainty associated with marine reserves. The indicator *The resilience of the local fish and shellfish stock* is designed to incorporate uncertainty into the full set of survey indicators. Participants expressed concerns during the focus group meetings regarding the unknown future value of environmental assets. In the case of this survey indicator, it is utilized for its contribution to a more certain estimation of future food and resource scarcity values. The type of value that this indicator captures is called *option value*—a type of nonuse value—which can be seen as the difference between valuation under conditions of certainty and uncertainty. Furthermore, one of the tenets of ecosystem-based management is the *precautionary principle*, which stresses a preference for using conservation measures like marine reserves to manage for uncertainty.

8. It is recommended that the Oregon Department of Fish and Wildlife conduct further research into defining and measuring *existence value*—another type of nonuse value—associated with marine reserves. The indicator *The protection and natural integrity of the marine ecosystem* captures this value by referring to the degree to which the marine ecosystem is perceived of as operating in a natural state. Participants of both focus groups expressed strong values for the overall condition of their local marine environment, even if that condition did not change the output of other ecosystem services. Stakeholder values related to biodiversity should also be explored within this same context, rather than with regard for its potential productive value.

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APPENDICES

Appendix A. Final Ecosystem Services from the First Meeting of Focus Groups

This section presents a description of each final ecosystem service identified by participants of the first meeting of the focus groups.

Table A.1. Matrix of the Input of Ecosystem Services into the Provision of Benefits

Ecosystem Service / **Benefit**	Physical activity	Human health: avoidance of pollution	Psychological and emotional health	Viewing of scenery	Viewing of wildlife	Using the beach	Marketing and consumption of seafood	Catching fish and invertebrates	Harvesting plants and algae	Food and resource security	Cultural identity	Ecological knowledge	Opportunity for stewardship and conservation
Provision of non-harvested fish					■			■					
Provision of harvested fish					■								
Environmental control of harvested fish populations					■		■	■					
Provision of non-harvested invertebrates					■								
Provision of harvested invertebrates					■				■				
Environmental control of harvested invertebrate populations					■		■						
Provision of non-harvested plants and algae				■									
Provision of harvested plants and algae				■									
Environmental control of harvested plant and alga populations							■						
Provision of marine mammals					■								
Provision of sea birds					■								
Provision of geologically mediated habitat and beach	■			■		■							
Provision of cognitive value												■	
Provision of cultural identity											■		
Provision of a socially valued seascape			■	■									
Provision of water and waves	■			■									
Environmental control of water quality		■											
Environmental control of air quality		■		■									
Environmental control of species richness					■								
Environmental control of ecosystem resilience										■			
Environmental control of overall ecosystem condition													■

Provision of non-harvested fish

This ecosystem service refers to the supply of individuals of species of fish that are not targeted for harvest. This ecosystem service provides the benefit of *Viewing wildlife* in combination with three other ecosystem services. This ecosystem service is distinct from *Provision of harvested fish,* which also provides benefits specific to the extraction of fish. These two services are distinguished due to the differing substitutability of the two services across the utility functions of their respective beneficiaries. Specifically, individuals seeking the benefit of viewing wildlife are unconcerned whether the fish they are seeing are harvested. In contrast, individuals seeking the benefit of catching a fish target only a subset of fish species.

Participants of both focus groups expect an increase in this ecosystem service as a result of their local marine reserve. Furthermore, they expect this increase to translate into an increase in the benefit of *Viewing wildlife*, especially underwater (i.e., to divers). Like the benefit of *Viewing of scenery* (see below), participants noted a range of activities motivated by this benefit, such as photography, visitation, choosing seaside restaurants and cafes over others, etc., in addition to diving. It should be noted, however, that both groups expect the creation of the marine reserve to be the immediate driver of any increases in activities motivated by the benefit of *Viewing wildlife*. An increase this ecosystem service should therefore be considered a secondary driver of change to this benefit that would occur over a longer time frame and would likely only impact the activity of diving.

Provision of harvested fish

This ecosystem service refers to the supply of individuals of those species of fish targeted by commercial and recreational fishermen. This ecosystem service contributes to the benefit of *Catching fish and invertebrates* in combination with the ecosystem service *Provision of harvested invertebrates*. As described above, this ecosystem service represents a set of species distinct from *Provision of non-harvested fish*.

Participants of the Redfish Rocks focus group expect an increase in this ecosystem service to result from their local marine reserve. They expect this increase, however, within, but not outside, their reserves and therefore do not expect this change to translate into an increase in the benefit of *Catching fish and invertebrates* outside of the reserve. In fact, both focus groups expect a decrease in this benefit.

Environmental control of harvested fish populations

This ecosystem service refers to the long-term maintenance of the population dynamics of those species of fish that are targeted for commercial or recreational fishing. This ecosystem service contributes to the benefit of *Marketing and consumption of seafood* in combination with three other services and the benefit of *Food and resource security* with four other ecosystem services. Stakeholders noted that one preference for their consumption and marketing of local seafood is the sustainability of the product, to which this ecosystem service contributes.

Participants of both focus groups expect a slight increase in this ecosystem service as a result of their local marine reserve. Furthermore, they expect this increase to translate into the benefit of *Marketing and consumption of seafood* captured outside of their local reserve.

Provision of non-harvested invertebrates

This ecosystem service refers to the supply of individuals of species of invertebrates that are not targeted for harvest, such as hard and soft corals. This ecosystem service contributes to the benefit of *Viewing wildlife* in combination with three other ecosystem services. This ecosystem service is similar to *Provision of non-harvested fish* regarding its distinction from the *Provision of harvested invertebrates*, the benefit it provides, and related changes as a result of the marine reserve (see description above).

Provision of harvested invertebrates

This ecosystem service refers to the supply of individuals of species of invertebrates that are targeted for commercial and recreational fishing. This ecosystem service contributes to the benefit of *Catching fish and invertebrates* in combination with *Provision of harvested fish*. This ecosystem service is similar to *Provision of harvested fish* regarding its distinction from the *Provision of non-harvested invertebrates*, the benefit it contributes to, and related changes as a result of the marine reserve (see description above).

Environmental control of harvested invertebrate populations

This ecosystem service refers to the long-term maintenance of the population dynamics of those species of invertebrates that are targeted for commercial or recreational fishing. This ecosystem service contributes to the benefit of *Marketing and consumption of seafood* in combination with three other services. This ecosystem service is similar to *Environmental control of harvested fish populations* regarding the benefit it contributes to and related changes as a result of the marine reserve (see description above).

Provision of non-harvested plants and algae

This ecosystem service refers to the supply of species of plants and algae that are not targeted for commercial and recreational harvest. This ecosystem service contributes to the benefit of *Viewing of scenery* in combination with three other ecosystem services. This ecosystem service is similar to *Provision of non-harvested fish* regarding its distinction from the *Provision of harvested plants and algae*. Participants of both focus groups expect a slight potential increase in this ecosystem service to result from the creation of their local marine reserve. Participants also expect this change to translate into a partial contribution to an increase in the benefit of *Viewing of scenery* as a result of their local marine reserve.

Provision of harvested plants and algae

This ecosystem service refers to the supply of species of plants and algae that are targeted for commercial and recreational harvest. This ecosystem service alone provides the benefit of *Harvesting plants and algae* and contributes to the provision of the benefit of *Viewing of scenery* with three other ecosystem services. This ecosystem service is similar to *Provision of harvested fish* regarding its distinction from the *Provision of non-harvested plants and algae*.

In addition, this ecosystem service contributes disproportionately to the benefit of *Viewing of scenery* because it includes Bull kelp, which participants noted was by far the most evident species of marine vegetation from a distance and underwater when diving, for example. Both focus groups expect a minor increase in this benefit “on the surface” via a potential increase in the provision of plants and algae (in particular Bull kelp), and a more substantial increase “under the water” via a potential decrease in damage to plants and algae. Participants noted a range of activities motivated by this benefit, such as photography, visitation, choosing seaside restaurants and cafes over others, etc., in addition to diving. Like the benefit of *Viewing of wildlife*, participants expect an increase in this benefit to result most immediately from the creation of the marine reserve. An increase this ecosystem service should therefore be considered a secondary driver of change to this benefit that would occur over a longer time frame. Any change to this benefit through a change in ecosystem services, however, could be fully attributed to a change in this ecosystem service, considering the low probability of a change in the other two contributing ecosystem services as a result of the creation of the marine reserve.

Environmental control of harvested plant and alga populations

This ecosystem service refers to the long-term maintenance of the population dynamics of those species of plants and algae that are targeted for commercial or recreational harvest. This ecosystem service contributes to the benefit of *Marketing and consumption of seafood* in combination with two other services. This ecosystem service is similar to *Environmental control of harvested fish populations* regarding the benefit it contributes to and related changes as a result of the marine reserve (see description above).

Provision of marine mammals

This ecosystem service refers to the supply of individuals of species of marine mammals. This ecosystem service contributes to the benefit of *Viewing of wildlife* in combination with three other ecosystem services. Participants expect a slight increase in this ecosystem service as a result of the marine reserve, most likely from an increase in sea lions. Like these three other ecosystem services, however, the contribution of this ecosystem service to the benefit of *Viewing of wildlife* is secondary to the effect of the regulatory action of creating the marine reserve. See the description of *Provision of non-harvested fish* for a discussion of this benefit.

Provision of sea birds

This ecosystem service refers to the supply of individuals of species of sea birds. This ecosystem service contributes to the benefit of *Viewing of wildlife* in combination with three other ecosystem services. Participants of both focus groups expect this ecosystem service to increase as a result of the marine reserve, as well as translate into an increase in the benefit of *Viewing of wildlife*. Furthermore, participants noted that bird watching is one of the most popular activities motivated by this benefit. An increase in this ecosystem service would therefore have a disproportionately large contribution to an increase in this benefit.

Provision of geologically mediated habitat and beach

This ecosystem service refers to the supply of the amount of sediment, rock, rocky reef, and sand to the local marine environment. This ecosystem service contributes to the benefits of *Viewing of scenery* in combination with three other ecosystem services, and solely provides the benefit of *Using the beach*, which refers to the opportunity to pursue activities on the beach. Participants of both focus groups expected no change in this ecosystem service as a result of the marine reserve, and thus this ecosystem service would not account for any long-term change in this benefit. Both groups do expect, however, an increase in activities motivated by this benefit to result directly from the creation of the marine reserve. Participants also noted that an increase in these activities could potentially result in increased trampling of intertidal organisms and habitats within the marine reserve, an interaction that suggests a trade-off in underlying ecosystem services.

Provision of cognitive value

This ecosystem service refers to the value of the marine ecosystem as an object of scientific study. This ecosystem service contributes solely to the benefit of *Ecological knowledge*. This ecosystem service is one of four listed in this analysis (including *Provision of a socially-valued seascape*, *Provision of cultural identity*, and *Provision of existence/conservation value*) that is formulated in order to describe the provision of a single benefit.

These ecosystem services are therefore categorically distinct from the others, and could be considered a quasi-ecosystem service. Specifically, they do not describe measurable biophysical features or qualities, but rather a benefit that is measured using social metrics. This attribute has two main implications. First, this category of indicators cannot be structurally linked to biophysical indicators, are not intended to be broken down via a production function, and are therefore measured via change in their corresponding benefits. Second, the regulatory action of creating a marine reserve is the sole driver of change to this ecosystem service and corresponding benefit. For example, in the case of this ecosystem service, it was noted by participants of both focus groups that the state of the ecosystem within the marine reserve is irrelevant to how much it is studied; rather, it is studied because it is a marine reserve, and the resulting state is only an outcome of that scientific observation.

For these reasons, measurement of this ecosystem service falls outside the scope of this analysis. This category of ecosystem services is included here, however, because it nevertheless represents an important source of welfare to stakeholders that can be measured using survey indicators. See the *Discussion* chapter for a more detailed discussion of this category of ecosystem services.

Provision of cultural identity

This ecosystem refers to the value of the marine ecosystem as an object of cultural identity. This ecosystem service contributes solely to the benefit of *Cultural identity*. This ecosystem service is one of the four categorically distinct ecosystem services (including *Provision of a socially-valued seascape*, *Provision of cognitive value*, and *Provision of existence/conservation value*) formulated in order to describe the provision of s single benefit. This attribute is discussed in further detail above and in the *Discussion* chapter. Like the three other categorically distinct ecosystem services, participants of both focus groups noted that this ecosystem service was central to their welfare, closely tied to the marine ecosystem, and sensitive to change. Furthermore, participants of both focus groups expected the creation of the marine reserve to increase this ecosystem service and its related benefit. Specifically, participants of the second meeting of the Otter Rock focus group noted that the marine reserve serves as “something to come together on and put us on the map.” Such change is also evident in the community of Port Orford and was mentioned by participants of the second meeting of the Redfish Rocks focus group.

Provision of a socially-valued seascape

This ecosystem service refers to the general aesthetic value of the marine ecosystem. This ecosystem service contributes solely to the benefit of *Psychological and emotional health*. This ecosystem service is one of four categorically distinct ecosystem services (including *Provision of cultural identity*, *Provision of cognitive value*, and *Provision of existence/conservation value*) formulated in order to describe the provision of s single benefit. This attribute is discussed in further detail above and in the *Discussion* chapter.

The benefit of *Psychological and emotional health* refers to the opportunity to be psychologically or emotionally affected by the aesthetics of the marine ecosystem and seascape. For example, participants described the beauty of the seascape and environs providing “inspiration,” “serenity,” “a chance to regroup,” “a sense of awe,” and that the ocean air “cleanses the soul.” While this benefit is deeply important to participants, neither group expects any related changes to result from their marine reserve. Furthermore, like similarly the three other categorically distinct ecosystem services, it is not intended to be broken down into biophysical features or qualities. In the words of one participant, the ecosystem that provides this benefit is “everything.” Measurement of this complex ecosystem service will require further research on the related values and attitudes of participants, which is outside the scope of this research.

Provision of water and waves
This ecosystem refers to the supply of ocean water and wave energy. This ecosystem service contributes to the benefits of *Physical activity* and *Viewing of scenery*. The benefit of *Physical activity* refers to the opportunity to obtain physical exercise through outdoor recreational activities, such as surfing, swimming, kite boarding, running, and kayaking. Participants of both focus groups expect this benefit to increase, in particular with an increase in kayaking within the marine reserves. Neither group, however, expects any change in this ecosystem service. The direct driver of the increase in this benefit is therefore the policy action of creating the marine reserve. See above for a discussion of the benefit of *Viewing of scenery*.

Environmental control of water quality
This ecosystem service refers to the maintenance of ocean water free of excess nutrients and pollutants. This ecosystem service contributes to the benefit of *Human health: avoidance of pollution* in combination with the ecosystem service *Environmental control of air quality*. This benefit refers to the ability to avoid air, water, and seafood that is considered polluted with regard to human health. It should be noted that this ecosystem service could be seen as a direct input to a number of activities, such as recreating in the water or consuming local seafood. In this analysis, however, the benefit of avoiding pollution is the factor that contributes to the decision of stakeholders to pursue these activities in clean water over polluted water. Participants of both focus groups expressed that this ecosystem service is very important to them. Neither group, however, expects a change in this ecosystem service or corresponding benefit as a result of their local marine reserve.

Environmental control of air quality
This ecosystem service refers to the maintenance of air that is free of excess particulates and pollutants. This ecosystem service contributes to the benefit of *Human health: avoidance of pollution* in combination with the ecosystem service *Environmental control of water quality*. Participants of both focus groups expressed that this ecosystem service is very important to them. Neither group, however, expects a change in this ecosystem service or corresponding benefit as a result of their local marine reserve.

Environmental control of species richness
This ecosystem service refers to the number of different species within a given area. It should be noted that this ecosystem service is not intended to represent a rubric for biodiversity or any other ecological concept. Rather, this ecosystem service contributes to the benefit of *Viewing of wildlife* in combination with four other ecosystem services, and does not serve as an input into the ecosystem service *Environmental control of ecosystem resilience*.

Participants of both focus groups expect an increase in this ecosystem service as a result of their local marine reserve. Furthermore, they expect this increase to translate into an increase in the benefit of *Viewing wildlife*, especially underwater (i.e., to divers). As is discussed above, however, that both groups expect the creation of the marine reserve to be the immediate driver of any increases in activities motivated by the benefit of *Viewing wildlife*. An increase in this ecosystem service should therefore be considered a secondary driver of change to this benefit that would occur over a longer time frame and would likely only impact the activity of diving.

Environmental control of ecosystem resilience
This ecosystem service refers to the maintenance of the ability of the marine ecosystem to resist damage and recover from natural disturbance and human impacts. This ecosystem service contributes to the

benefit of *Food security and sustainability* with four other ecosystem services. Participants of both focus groups expect an increase in this ecosystem service as a result of their local marine reserve. Furthermore, they expect this increase to translate into an increase in the benefit of *Food security and sustainability*.

This ecosystem service is categorically distinct from others in this analysis with regard to how it is utilized. This service resembles what is referred to in the Millennium Ecosystem Assessment (2005) as a *supporting* ecosystem service. The academic literature generally discourages the direct valuation of supporting services because their value is inherent in the value of the other three types of services (Hein et al. 2006). This ecosystem service is nonetheless included in this analysis in order to address uncertainty in environmental decision-making. Uncertainty in scientific analysis, human values and preferences, and institutional effects (Rudd 2007) can arise from a range of sources (Regan et al. 2002). The economic effects of uncertainty are described by Barbier (2007) as pertaining to the *ex ante* estimation of values, which can be expressed with regard to the future value of environmental assets. In the case of this ecosystem service, it is utilized for its contribution to a more certain estimation of future food and resource scarcity values. The type of value that this benefit supports is called *option value*—a type of nonuse value (Morton 1999)—which can be seen as the difference between valuation under conditions of certainty and uncertainty (Barbier 2007). Furthermore, one of the tenets of ecosystem-based management is the precautionary principle (McCleod et al. 2005), which stresses a preference for using conservation measures like marine reserves to manage for uncertainty.

Environmental control of overall ecosystem condition

This ecosystem service refers to the degree to which the marine ecosystem is perceived of as operating in a natural state. This ecosystem service contributes solely to the benefit of *Opportunity for stewardship and conservation*. This ecosystem service is one of four categorically distinct ecosystem services (including *Provision of cultural identity*, *Provision of cognitive value*, and *Provision of a socially-valued landscape*) formulated in order to describe the provision of s single benefit. This attribute is discussed in further detail above and in the *Discussion* chapter. Participants of both focus groups expect this ecosystem service and its corresponding benefit to increase as a result of their local marine reserve.

Like the ecosystem service *Environmental control of ecosystem resilience*, this ecosystem service is also categorically distinct with regard to how it is utilized. It could be considered a supporting ecosystem service (Millennium Ecosystem Assessment 2005) or an intermediate ecosystem service, and contributes to a benefit that supports what is called *existence* value—a type of nonuse value. In these senses, this ecosystem service can be considered inappropriate for valuation (Turner et al. 1997). Participants of both focus groups, however, expressed strong values for the overall condition of their local marine ecosystem, even that condition did not change the output of other ecosystem services. In other words, participants valued this ecosystem service as a distinct ecological endpoint.

Like the other three categorically distinct ecosystem services this ecosystem service does not describe measurable biophysical features or qualities. Rather, it is measured by conservation and stewardship actions, and therefore the regulatory action of creating a marine reserve is the sole driver of change to this ecosystem service and corresponding benefit. The ecological result of that action is highly uncertain, yet the benefit is already conferred through conservation.

Appendix B. Bioindicators Identified from Literature and Expert Opinion

Indicator/Index Category	Empirical Indicator/Index
Water condition and quality	Temperature[3] Salinity[3] Chlorophyll a[3] Dissolved oxygen[3] Light/turbidity[3] Sedimentation rate[3] Nutrient loading[3] Density of suspended toxins[3] Density of suspended bacteria[3]
Community composition and structure	Relative species abundance[2] Extracted organism density[2] Extracted organism biomass[2] Extracted organism individual size[2] Mean individual fish length[3] Mean individual fish weight[3] Trophic level of landings[4] Food web integrity[3] % Predatory fish[4] Density profile per species[5] Species habitat correlations[2] Benthic cover[5] Species richness/diversity index[3]
Habitat composition and structure	Habitat distribution[3] Habitat complexity[3] Habitat integrity[3] Abiotic habitat diversity[3] Biotic habitat diversity[3] Bull Kelp percent cover (subsurface)[2] Bull Kelp biomass[2] Understory kelps and algal presence[2] Understory kelps and algal percent cover[2] Understory kelps and algal density[2] Area showing signs of recovery[3] Area under no or reduced human impact[3]
Population composition and structure	*Rockfish* Rockfish length distribution[1] Rockfish age distribution[1] Total biomass[3] Post-settlement juvenile abundance[1] *Invertebrates* Invertebrate presence[2] Invertebrate relative abundance[2] Invertebrate abundance[2] Invertebrate density[2]

Indicator/Index Category	Empirical Indicator/Index
	Total biomass[3] *Fish* Fish presence[3] Fish abundance[3] Fish density[3] Total biomass[3] *Flora* Bull Kelp percent cover (surface)[2] Bull Kelp percent cover (subsurface)[2] Bull Kelp biomass[2] Understory kelps and algal presence[2] Understory kelps and algal percent cover[2] Understory kelps and algal density[2] *Focal species* Abundance of endemic species[3] Abundance of exotic species[3] Abundance of flagship species[3] Abundance of indicator species[3] Abundance of keystone species[3] Abundance of target species[3] Abundance of vulnerable species[3] *Breeding stock* Abundance of breeding stock[3] Biomass of breeding stock[3] Fecundity of breeding stock[3]
Fishery-Dependent	CPUE by nearshore location/bottom type[6] CPUE[3] CPUE per species[3] CPUE variation[3] Type[3] Effort[3] Total landings[3]

Sources:
1. Selina Heppell, Oregon State University
2. Alix Laferrier, Oregon Department of Fish and Wildlife
3. Pomeroy et al. 2004
4. http://www.indiseas.org
5. Petellier et al. 2009
6. James Golden, Golden Consulting

Appendix C. Supply Function of Final Ecosystem Services from the First Meeting of Focus Groups

Ecosystem services down the left column are analyzed for their interaction with ecosystem services across the top row of the matrix. Instances of one ecosystem service serving as an input into the production of another are denoted with blue boxes containing a + symbol; negative inputs are denoted with orange boxes containing a **-** symbol; and context- or stakeholder-dependent interactions are denoted with yellow boxes containing a +/- symbol. Ideally, ecosystem services should not be aggregated if they interact in a positive (productive), negative, or context-dependent way (i.e., they are connected by a symbol in the matrix).

Note: Ecosystem services below serve as inputs into ecosystem services to the right →	Provision of non-harvested fish	Provision of harvested fish	Environmental control of harvested fish	Provision of non-harvested invertebrates	Provision of harvested invertebrates	Environmental control of harvested invertebrate populations	Provision of non-harvested plants and algae	Provision of harvested plants and algae	Provision of marine mammals	Provision of sea birds	Provision of geologically mediated habitat and beach	Provision of cognitive value	Provision of cultural identity	Provision of a socially valued seascape	Provision of water and waves	Environmental control of water quality	Environmental control of air quality	Environmental control of species richness	Environmental control of ecosystem resilience	Provision of existence/conservation value
Provision of fish		+/-	+/-	-	-	-	-	-	+	+						+/-				
Provision of harvested fish	+/-		+/-	-	-	-	-	-	+	+						+/-				
Environmental control of harvested fish populations	+/-	+																		
Provision of invertebrates	+	+			+/-	+/-	-	-	+	+						+				
Provision of harvested invertebrates	+	+		+/-		+/-	-	-	+	+						+				
Environmental control of harvested invertebrate populations				+/-	+															
Provision of plants and algae	+	+		+	+			+/-								+	+			
Provision of harvested plants and algae	+	+		+	+											+	+			
Provision of marine mammals	-	-		-	-															
Provision of sea birds	-	-		-	-															
Provision of geologically mediated habitat and beach	+	+		+	+		+	+	+	+										
Provision of cognitive value																				
Provision of cultural identity																				
Provision of a socially valued seascape																				
Provision of water and waves							-	-												
Environmental control of water quality	+	+	+	+	+	+	+	+	+	+							+			
Environmental control of air quality	+	+	+	+	+	+	+	+	+	+						+				
Environmental control of species richness																				
Environmental control of ecosystem resilience																				
Provision of existence/conservation value																				

Appendix D. Results of the Second Meeting of Focus Groups: Metrics and Measurement of Survey Indicators

The quality of ocean water for purposes of human contact and consumption of seafood

This survey indicator can be measured using seven bioindicators (see Table 3.4), four of which were identified by participants of the second meeting of the focus groups. When asked what came to mind when presented indicator 1, which is most similar to this survey indicator, participants noted that they associate the water quality in their local ocean environment with local point and non-point sources of pollution. When asked how they would know if indicator 1 were changing, participants responded that they would have to rely on scientific monitoring and standard reporting, and that they had heard of indicator species in the intertidal zone that respond positively to increased nutrification. Also, participants suggested that Oregon start a program similar to Mussel Watch[5].

The number of non-harvested fish

This survey indicator can be measured using seven bioindicators, four of which were identified by participants of the second meeting of both focus groups (see Table 3.4). When asked what came to mind when presented indicator 4, which is the survey indicator most similar to this, participants noted that they associate the abundance of all types of fish with a visual picture of large schools of large fish. When asked how they would know if indicator 4 were changing, participants responded that they would visually observe a change while diving and would learn of changes through biological surveys. Also, participants at the second meeting of both focus groups noted that a change in indicator 4 would be observable through changes in the health and abundance of sea birds.

The number of harvested fish, The number of harvested shellfish,* and *The number of harvested plants and algae

This survey indicator can be measured using various bioindicators (see Table 3.4). When asked what came to mind when presented indicator 8, which is most similar to these survey indicators, participants noted that they associate the supply of seafood with the composition and strength of their local economy. These metrics are measured primarily with socioeconomic indicators, which are discussed further in the Discussion section. All bioindicators presented in this section are therefore either selected from academic literature and expert opinion, or derived from responses to indicators 4, 5, and 6.

The number of non-harvested shellfish

This survey indicator can be measured using eight bioindicators, four of which were identified by participants of the second meeting of both focus groups (see Table 3.4). When asked what came to mind when presented indicator 5, which is the survey indicator most similar to this, participants described pictures of abundant sea urchins, mussels, clams, and crabs. Since these organisms are harvested, however, they will be included in the measurement of the survey indicator *The number of harvested shellfish*. For the purposes of measuring this survey indicator, it will be assumed that participants of the second meeting of the focus group would identify similar metrics for non-harvested species of shellfish. When asked how they would know if indicator 5 were changing, participants noted that changes would be observable through visual census of constituent species, as well as the health and abundance of seabirds.

[5] See http://ccma.nos.noaa.gov/about/coast/nsandt/musselwatch.aspx

The number of non-harvested plants and algae

This survey indicator can be measured using four bioindicators, none of which were identified by participants of the second meeting of both focus groups (see Table 3.4). When asked what came to mind when presented indicator 6, which is the survey indicator most similar to this, participants described plants and algae floating on the surface of the water and washed up on the beach. Participants noted, however, that the uprooting of plants and algae occurs episodically, mostly after storm events. Long-term measurement of this indicator would therefore be more difficult to observe. When asked how they would know if indicator 6 were changing, participants were not confident in a long-term metric. All bioindicators presented in this section are therefore selected from academic literature and expert opinion.

The number of marine mammals

This survey indicator can be measured using three bioindicators, all of which were identified by participants of the second meeting of both focus groups (see Table 3.4). When asked what came to mind when presented indicator 7, which is the survey indicator most similar to this, participants described the abundance of whales and sea lions. When asked how they would know if indicator 7 were changing, participants noted that while it is easy to observe the abundance of marine mammals at any given time, seasonal and long-term fluctuations in abundance would be difficult to observe and they would therefore rely on biological monitoring. Participants did note, however, that whale watching operators likely maintain relevant data.

The number of sea birds

This survey indicator can be measured using two bioindicators, all of which were identified by participants of the second meeting of both focus groups (see Table 3.4). When asked what came to mind when presented indicator 7, which is the survey indicator most similar to this, participants described the abundance of sea birds. When asked how they would know if indicator 7 were changing, participants responded that the abundance of sea birds is cyclical and episodic. Participants therefore noted that they would rely on biological monitoring to learn of changes to this survey indicator.

A natural and wild Oregon seascape to view and take in

This survey indicator cannot be measured using bioindicators. When asked what came to mind when presented indicator 9, which is the survey indicator most similar to this, participants described a relatively pristine and undeveloped shoreline. When asked how they would know if indicator 9 were changing, participants responded that developments such as buildings and wave energy buoys would represent a decrease. These metrics, while apparently simple, do not correspond to biophysical features or qualities, and therefore are outside the scope of this analysis. Further research, however, into the measurement of this indicator is warranted.

An Oregon ocean that provides personal and scientific discovery

This survey indicator cannot be measured using bioindicators. When asked what comes to mind when presented indicator 10, which is the survey indicator most similar to this, participants described experiences of exploring and being surprised by their local marine environment, as well as the presence of scientific research efforts in their community. Participants did not describe any natural features or qualities that correlated with scientific research because scientists choose to study the marine environment regardless of its condition. When asked how they would know if indicator 10 were changing, participants responded that while their personal experiences are isolated and difficult to track, they would expect an increase in marine science programs in local schools; the number of researchers visiting; the amount of research conducted; the number of divers visiting; and the number of field trips and summer programs held. Participants of the second meeting of the Otter Rock focus group in particular noted that it is easy to observe increases in research at the Hatfield Marine Science Center and the Oregon Aquarium. In addition, however, participants noted that the creation of their local marine reserve is evidence of an increase in this indicator. See the Discussion section for a discussion of the importance of this result.

A community identity defined by a connection with the ocean

This survey indicator cannot be measured using bioindicators (see Table 3.4). When asked what came to mind when presented indicator 11, which is the survey indicator most similar to this, participants described the cultural and socioeconomic composition of their community. Specifically, participants discussed the presence of a working waterfront; a local economy that flows from fish and fishing and includes a stable fishing fleet and processing business; a commercial, educational, and artistic culture that highlights fish, fishing, and the ocean; tourism; ocean-based recreation such as surfing, kayaking, and diving; and the attraction of retired residents. When asked how they would know if indicator 11 were changing, participants described an increase in the metrics described above. In addition, however, participants noted that the creation of their local marine reserve is evidence of an increase in this indicator. See the Discussion section for a discussion of the importance of this result.

The resilience of the local fish and shellfish stock

This survey indicator can be measured using three bioindicators, none of which were identified by participants of the second meeting of both focus groups (see Table 3.4). When asked what came to mind when presented indicator 8, which is the survey indicator most similar to this, participants described aspects of the market for seafood. Since indicator 8 did not elicit discussion of the security and sustainability of the local fishery, all bioindicators presented in this section are selected from academic literature and expert opinion. It should be noted, however, that the values underlying this indicator are profound and complex, and warrant further research outside the scope of this analysis. See the *Discussion* chapter for a discussion of this topic.

The variety of plants, animals, and habitats

This survey indicator can be measured using six bioindicators, none of which were identified by participants of the second meeting of both focus groups (see Table 3.4). When asked what came to mind when presented indicator 13, which is the survey indicator most similar to this, participants described a picture of a vibrant and diverse nearshore community, including a range of organisms in the intertidal zone and underwater habitats visible to divers. When asked how they would notice if indicator 13 were changing, participants noted that observation of a change in the diversity of organisms would be more difficult to observe casually than a change in the abundance of organisms, so they would likely rely on biological monitoring to learn of changes.

The protection and natural integrity of the marine ecosystem

This survey indicator can be measured using three bioindicators, none of which were identified by participants of the second meeting of both focus groups (see Table 3.4). It should be noted, however, that the specification of this indicator is incomplete and warrants further research outside the scope of this analysis.