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Title: A Community-Based Approach for Evaluating Tradeoffs Across Marine Ecosystem Services in Oregon

Abstract approved:

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Randall S. Rosenberger

As competing uses of our coastlines increase, natural resource agencies are employing marine spatial planning (MSP) to designate areas for different uses or activities in order to reduce conflicts while achieving ecological, economic and social objectives. A central challenge of implementing MSP is development of a rigorous approach for analyzing tradeoffs across the provision of ecosystem services (i.e., the benefits humans receive from nature). This study develops an operational approach to this problem that is founded on community-based methods, ecological production theory, and multi-criteria decision analysis (MCDA). The approach merges ecological models with surveys to identify marine ecosystem services for use in tradeoff analysis. The approach allows for a single set of marine ecosystem services to at once be valued by local stakeholders and measured by biologists, thus connecting social and biological monitoring efforts.

To develop the approach in a real-world context, I examined ecosystem services associated with nearshore marine ecosystems in Oregon, where marine reserves are being introduced for biodiversity conservation. I worked with stakeholder focus groups in three Oregon communities to identify 24 marine ecosystem services. I then linked the ecosystem services with ecological indicators, which I then consolidated to derive 11 items for use in a survey-based tradeoff analysis exercise. I administered the survey to a nonrandom sample of stakeholders in Oregon (n=31), from which their relative preferences and preference weights for ecosystem services were derived. The weights and preference measures may then be used in MSP decision-making.

Furthermore, I grouped the stakeholder survey data in three ways: by location of residence (coastal vs. non-coastal), by eight categories of affiliation (e.g., business owners, conservationists, commercial and recreational fishers, etc.), and by resource use patterns. I then analyzed the various groupings of stakeholders for within- and between-group homogeneity of preferences. Results of the analyses showed that there are statistically significant variations in preferences within and between most groupings. Capturing the variations in stakeholder preferences is important when developing policies that affect different stakeholder groups. Thus, when implementing the survey instrument, I suggest random sampling of stakeholders stratified by location, affiliation, and resource use.

This study provides one of the first examples of a systems-based approach to ecosystem service valuation operationalized to inform MSP, and novel features of the approach have a number of implications for advancing marine research and management. First, by using stakeholders to identify ecosystem services, the approach allows for a tailored implementation of ecosystem-based management at the community level. Second, by integrating ecological and economic information on the provision and value of ecosystem services, the approach provides relevant data for MSP decision-making during the siting, evaluation, and monitoring stages. And third, by applying both stated-preference and MCDA methods, the approach may capture the array of values represented by diverse stakeholder groups.

A Community-Based Approach for Evaluating Tradeoffs Across
Marine Ecosystem Services in Oregon

by
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Peter M. Freeman, Author

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## TABLE OF CONTENTS

## TABLE OF CONTENTS (Continued)

**TABLE OF CONTENTS (Continued)**

**TABLE OF CONTENTS (Continued)**

**LIST OF FIGURES**

## LIST OF TABLES

## DOCUMENT GUIDE

The principal purpose of this study is to develop and implement an operational approach for analyzing tradeoffs across the provision of ecosystem services (i.e., the benefits humans receive from nature). This study was motivated by the need to evaluate marine reserve effectiveness in accordance with the principles and practices of ecosystem-based management, marine spatial planning, natural resource economics, multi-criteria decision analysis, and community-based marine resource management in Oregon. I developed the approach with regard to the objectives and criteria provided by these policies, and implemented it in three study communities in Oregon.

This document is organized into four chapters. Chapter 1 is titled, “Conceptual foundations of an approach to analyze tradeoffs across marine ecosystem services.” This chapter introduces the policy context for this study, as well as the theory and practice of valuing marine ecosystem services. Chapter 2 is titled, “Development and implementation of an approach to analyze tradeoffs across marine ecosystem services.” This chapter details the operational approach and its implementation with three stakeholder focus groups in Oregon. The research questions addressed in this chapter test the ability of the approach to meet its stated objectives in real Oregon communities. Chapter 3 is titled, “Oregon stakeholder values for marine ecosystem services: an implementation study.” This chapter details the development and administration of a survey instrument to measure stakeholder values for marine ecosystem services, as well as statistical analysis of the survey results. The research questions addressed in this chapter are hypothesis-based and analyze variation in preferences for ecosystem services within and across different stakeholder groups. Chapter 4 is titled, “A perspective on development and implementation of an approach to analyze tradeoffs across marine ecosystem services in Oregon.” This chapter synthesizes the methods and results of Chapters 2 and 3 with regard to the implications of this work for marine policy, management, and planning.

# CHAPTER 1
# CONCEPTUAL FOUNDATIONS OF AN APPROACH TO ANALYZE TRADEOFFS ACROSS MARINE ECOSYSTEM SERVICES

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## 1.1 INTRODUCTION

This chapter details the policy context and conceptual foundations of the approach developed and implemented in this study. Every approach is designed to meet certain objectives and criteria, which in turn determine its final products and potential applications. This chapter presents the policies and practices in marine resource management and natural resource economics that define the criteria for design of the approach, the general objectives of the approach, and the criteria for meeting those objectives.

### 1.1.1 Marine Reserves in Oregon

This study was largely motivated by the effort of Oregon Sea Grant and the State of Oregon's Department of Fish and Wildlife to evaluate the ecological and socioeconomic tradeoffs associated with emerging nearshore management actions. The most recent of these actions is the siting of *marine reserves*, which were first called for in March of 2008 when then Oregon Governor Kulongoski signed Executive Order 08-07 (Office of the Governor, 2008).

Marine reserves are defined in Oregon as areas "protected from all extractive activities, including the removal or disturbance of living and non-living marine resources, except as necessary for monitoring or research to evaluate reserve condition, effectiveness, or impact of stressors" (Oregon Ocean Policy Advisory Council, 2008, p. 6). Within marine reserves in Oregon, extractive practices are defined as fishing, hunting and harvesting of shellfish, other invertebrates, kelp and seaweed (Office of the Governor, 2008). 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 (Office of the Governor, 2008).

Marine reserves are technically fully protected *marine protected areas* (MPAs). MPAs are defined in the United States as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein" (Executive Order 13158, 2000, p. 34909). MPAs can be established pursuant to a variety of goals and the level of protection within MPAs can vary considerably. Marine reserves in Oregon are located and sized in order to generate economic benefits and biophysical outcomes sufficient to meet the following 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" (Oregon Ocean Policy Advisory Council, 2008, p. 1). Marine reserves were designed by community groups that included local fishermen and other members of the local community. Some of these individuals participated in this research as focus group members and survey respondents.

As of January 1st, 2012, two marine reserves have been fully implemented in Oregon state waters: Redfish Rocks Marine Reserve in Port Orford, and Otter Rock Marine Reserve north of Newport. The Redfish Rocks Marine Reserve is 2.6 square miles in area, and is bordered by a 5 square mile MPA extending seaward to the Oregon state waters marine boundary within which bottom-disturbing fishing gear is prohibited, but authorized salmon and crab fishing is allowed. The Otter Rock Marine Reserve is 1.3 square miles in area and is not buffered by a MPA.

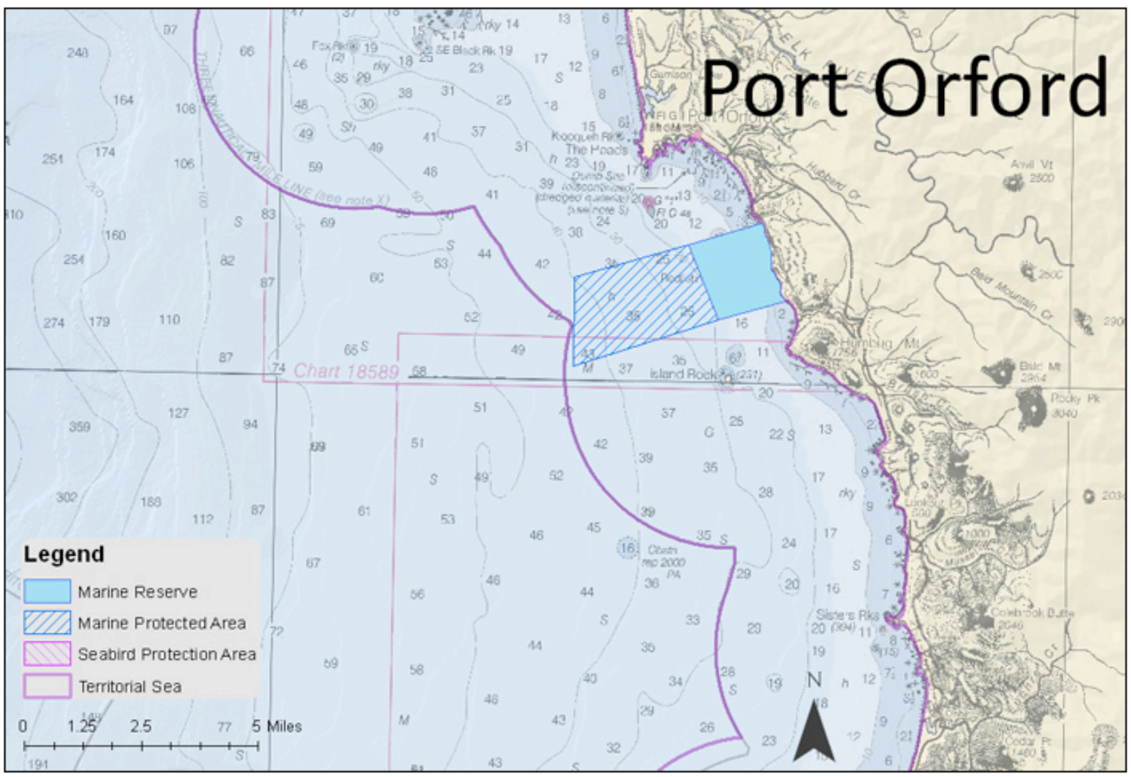


**Figure 1.** Map of Redfish Rocks Marine Reserve and Marine Protected Area

Planning map of the Redfish Rocks Marine Reserve and MPA south of Port Orford, OR, implemented in January, 2012. The Redfish Rocks Marine Reserve is 2.6 square miles in area, and is bordered by a 5 square mile MPA extending seaward to the Oregon state waters marine boundary within which bottom-disturbing fishing gear is prohibited, but authorized salmon and crab fishing is allowed. Source: (State of Oregon, 2012a)

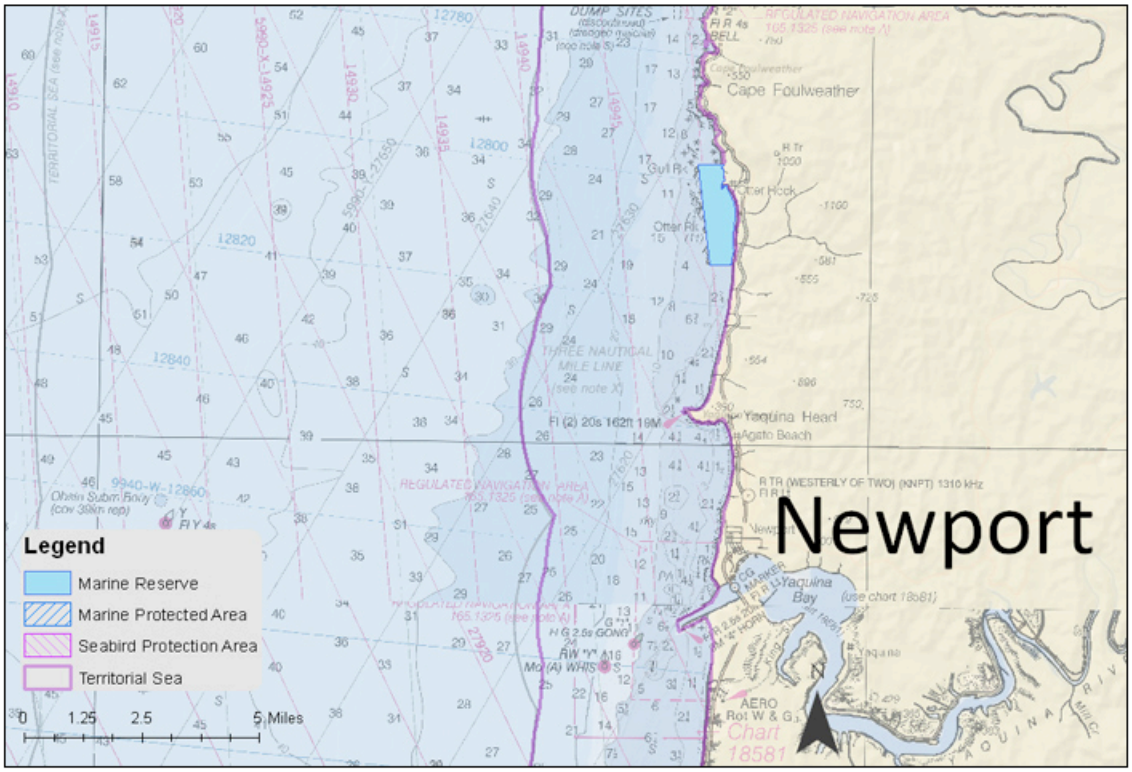


**Figure 2.** Map of Otter Rock Marine Reserve

Planning map of the Otter Rock Marine Reserve located in Otter Rock, OR, north of Newport, OR, implemented in January, 2012. The Otter Rock Marine Reserve is 1.3 square miles in area and is not buffered by a MPA. Source: (State of Oregon, 2012b)

Before implementation, these two marine reserves were in a *pilot phase* to allow for the collection of baseline ecological and socioeconomic information. This study contributes to that baseline effort. A full baseline study requires the description of initial biophysical and socioeconomic conditions, including estimated market and nonmarket costs and benefits, as well as a method for tracking long-term change to these metrics. While this study was applied specifically to the establishment of marine reserves in Oregon, the approach and lessons learned from its implementation are applicable to the siting and evaluation of any MPA—an increasingly common practice in the United States and other countries worldwide (Foley et al., 2010).

### 1.1.2 Ecosystem-Based Marine Spatial Planning

The design and siting of MPAs (hereafter used to refer to marine reserves and less than fully restrictive MPAs) utilizes *marine spatial planning* (MSP), which can be defined as “a planning process…[that] identifies which areas of the ocean are appropriate for different uses or activities in order to reduce conflicts and achieve ecological, economic and social objectives (Lester et al., 2012). MSP is a conceptually simple tool, and can therefore also be applied quite simply. While neither the goals of MSP nor MPAs are required to align with any specific policy, both tools are increasingly used to implement *ecosystem-based management* in Oregon and elsewhere in the United States and internationally (Foley et al., 2010; Halpern et al., 2010). Ecosystem-based management (EBM) can be defined as "an integrated approach to management that considers the entire ecosystem, including humans" (McLeod & Lubchenco, 2005, p. 1) and generally characterized as utilizing a holistic approach to natural resource management that considers economic costs and benefits to stakeholders (Arkema et al., 2006; Crowder & Norse, 2008; Curtin & Prellezo, 2010; Levin & Lubchenco, 2008; Pikitch et al., 2004).

The goal of EBM 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 (Levin & Lubchenco, 2008; McLeod & Lubchenco, 2005). Economic and social objectives are essential to EBM (Curtin & Prellezo, 2010), but it is advocated that common social values and preferences be considered within a scientific understanding of the ecosystem (Crowder & Norse, 2008).

In accordance with regional (West Coast Governors Agreement on Ocean Health, 2008) and national guidelines (White House Council on Environmental Quality, 2010), the process of establishing MPAs in Oregon is grounded in the principles of EBM. The application of MSP to implement EBM has been termed *ecosystem-based marine spatial planning* (EB-MSP) by Foley et al. (2010). Crowder & Norse 2008 provide the need for EB-MSP: "ecosystems are places, and ecosystem-based management is therefore inherently place-based…Moreover, social, cultural, economic, and political attributes overlay these biophysically defined places. Thus, approaches that integrate natural and social scientific perspectives on defining and managing places at sea are necessary to implement ecosystem-based management" (p. 772). As such, EB-MSP must meet a wide range of procedural and outcome-based objectives. The approach developed in this study was guided by the need of the state of Oregon to meet two of those objectives in particular: the consideration of common social values and preferences within a scientific understanding of the ecosystem (Crowder & Norse, 2008), and; the conservation of the long-term capacity of social-ecological systems to sustain the delivery of a broad suite of ecosystem services (McLeod & Lubchenco, 2005).

### 1.1.3 Marine Ecosystem Services

*Ecosystem services* can be defined generally as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life…They maintain biodiversity and the production of ecosystem goods…In addition to the production of goods, ecosystem services are the actual life-support functions, such as cleansing, recycling, and renewal, and they confer many intangible aesthetic and cultural benefits as well" (Daily, 1997, p. 3). Ecosystem services have become central to the implementation of both EBM and MSP. In 2009, President Obama established an Interagency Ocean Policy Task Force (OPTF) to develop recommendations for a national ocean policy and framework for MSP. The OPTF lists "ensur[ing] resilient ecosystems and their ability to provide sustained delivery of ecosystem services" as one of its seven national goals, and relates ecosystem services to MSP by recommending coastal and MSP as a policy tool suited to the preservation and enhancement of ecosystem services "because they are centrally incorporated into the [MSP] Plan as desired outcomes of the process and not just evaluated in the context of individual Federal or State agency action" (White House Council on Environmental Quality, 2010, p. 44).

The OPTF recommendations, however, do not provide explicit guidelines on the definition, identification, assessment, and valuation of ecosystem services. Similarly, neither does the State of Oregon. Furthermore, as discussed in Section 1.2.1.2, few researchers have operationalized approaches for such an analysis (Nahlik et al., 2012). The approach developed in this study aims to achieve these objectives. The topic of defining and identifying ecosystem services is discussed in Section 1.2.1.2. The topic of assessing and valuing ecosystem services is discussed in Section 1.2.5. These discussions include theoretical and practical considerations and criteria from academic literature that are incorporated into the approach.

## 1.2 A SYSTEMS-BASED APPROACH TO ECOSYSTEM SERVICE VALUATION

Each field of social science studies human behavior with respect to its own specific category of variables. This study draws mostly from the field of *natural resource economics*, which itself has its roots in welfare economics. The field of welfare economics studies behavior with respect to individually held values. Values can be defined as "the preferences, principles and virtues that we (up)hold as individuals or groups" (Chan et al., 2012, p. 3). Environmental values systems are complex (Norgaard, 2010; Norton & Noonan, 2007). To economists, values manifest themselves as expressions of importance or desirability (Wainger & Boyd, 2009) which are measured according to individuals' own assessments of their wellbeing (Bockstael et al., 2000). Therefore, natural resource economics measures the value of nature as the importance or desirability of natural features and qualities with respect to individual wellbeing.

Economics does not account for all types of values, however. The economic approach to valuation considers only *anthropocentric* and *utilitarian* values at the exclusion of other values, such as eco-centric values (Heal et al., 2005). As explained in Section 1.2.2, however, anthropocentric values are quite broad. This value system not only provides the basis for the concept of ecosystem services and the practice of MSP (Foley et al., 2010), but it also defines the theoretical and practical aspects of natural resource economics that underlie the approach developed in this study. The following section discusses the types of values economics includes and excludes, and how they relate to the way in which economists systematically conceptualize the environment with respect to human welfare. Specifically, this concept has bearing on the definition of ecosystem goods and services used in the approach, as well as the description of the ecological relationships underlying their provision.

### 1.2.1 Ecological Production Theory

The anthropocentric and utilitarian nature of economic value implies that humans value a thing only for its contribution to the production of other things or for its being a desired end in itself as a commodity. The former type of value is called *instrumental value*; the latter is called *final* or *terminal value* (T. Brown, 1984). Applying these types of values and the relationship between them to the environment allows for a *systems-based* approach to ecological valuation, called *ecological production theory* (Boyd & Krupnick, 2009; Brown & Bergstrp, 2007; Chee, 2004; EPA Science Advisory Board, 2009; Heal et al., 2005; Wallace, 2007). Traditional economic production theory frames the industrial economy as a system wherein raw materials are transformed by factors of production into commodities that reach a final consumer. Similarly, ecological production theory depicts nature as a system wherein biophysical conditions are transformed by natural processes into valued commodities. Ecological production theory serves as the philosophical and operational foundation for the approach developed in this study.

Operationally, ecological production theory links the provision of ecosystem services to the delivery of valued benefits. In order to make these estimations, economists employ two types of functional relationships. One predicts how natural features are related to the capacity of an ecosystem to supply ecosystem services. This function is called an *ecological production function*. A second connects ecosystem services to demand for them. This function is called an *economic demand function* (Heal et al., 2005; Wainger & Boyd, 2009). Demand is a function of resource users and their preferences. The linkages between these two functions are illustrated in Figure 3 (Adapted from Wainger & Boyd, 2009, p. 102), which serves as the conceptual guide for the approach developed in this study. The individual components of the conceptual framework below and the vocabulary used to describe them are discussed in the following sections of this chapter.

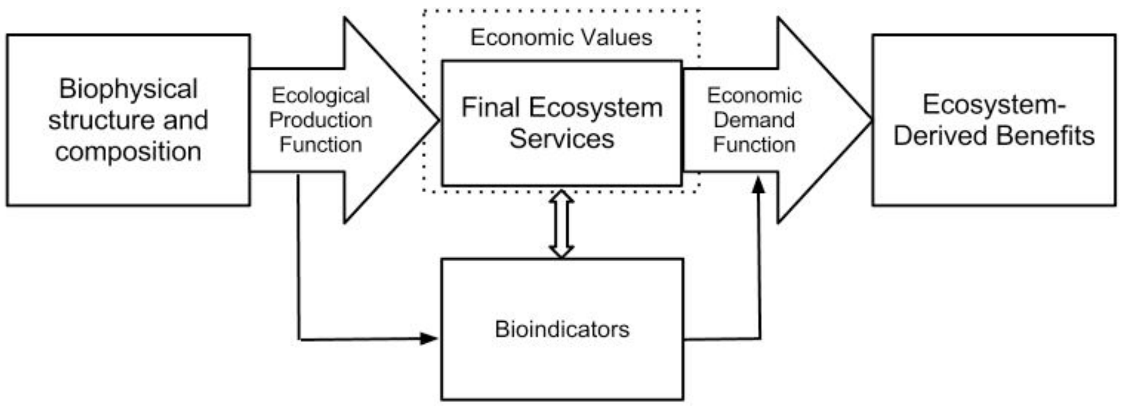


**Figure 3.** Diagram of the conceptual framework for economic valuation of ecosystem services

Diagram of a systems-based conceptualization of the process by which biophysical structure and composition translates into the delivery of valued benefits. Block arrows represent functions to be calculated. Blocks represent inputs and outputs of functions. Solid line arrows depict the process of identifying and utilizing bioindicators in valuation—a step central to this study but not required. Adapted from Wainger & Boyd, 2009, p. 102.

#### *1.2.1.1 Ecosystem-Derived Benefits and Human Wellbeing*

The central component of an approach to evaluate ecosystem service tradeoffs is a system of classifying ecosystem services. It is widely argued within the field of natural resource economics that ecosystem service classification systems should distinguish between ecosystem services and ecosystem-derived benefits (Boyd & Banzhaf, 2007; Boyd & Krupnick, 2009; Fisher et al., 2008; Fisher et al., 2009; Hein et al., 2006; Wallace, 2008). An economic benefit is the thing valued and demanded by a consumer. *Ecosystem-derived benefits* (the far right side of Figure 3) can be generally defined as "valued goods and experiences" derived from environmental components, and are considered the level at which people can most easily relate ecosystems to themselves (Chan et al., 2012). In other words, benefits are what ecosystem services are utilized for. Sometimes this utilization can be immaterial, as in the case of an experience. In other cases, benefits are utilized through material processes. In fact, one widely qualification to defining ecosystem-derived benefits is “[they] are typically generated by ecosystem services in combination with other forms of capital” (Fisher & Turner 2008, p. 2052).

Fisher et al. (2008) also note that ecosystem-derived benefits have a “direct impact on human welfare” (p. 2052). This aspect has implications for the practice of economic valuation, which only allows benefits that are directly valued to be aggregated (Fisher et al., 2008). Benefits are also human constructs, and their diversity is limited only by individually held values with respect to their wellbeing. For the purpose the approach developed in this study benefits can be categorized according to three types of determinants of *human wellbeing*: economic wellbeing, social wellbeing, and personal wellbeing (Busch, Gee, Burkhard, & Lange, 2011). Figure 4 below presents this typology applied to a range of marine ecosystem services expected to be impacted by offshore wind energy development in the German North Sea. It should be noted, however, that many benefit and wellbeing typologies exist (Angulo-Valdés & Hatcher, 2010; Constanza et al., 2008).

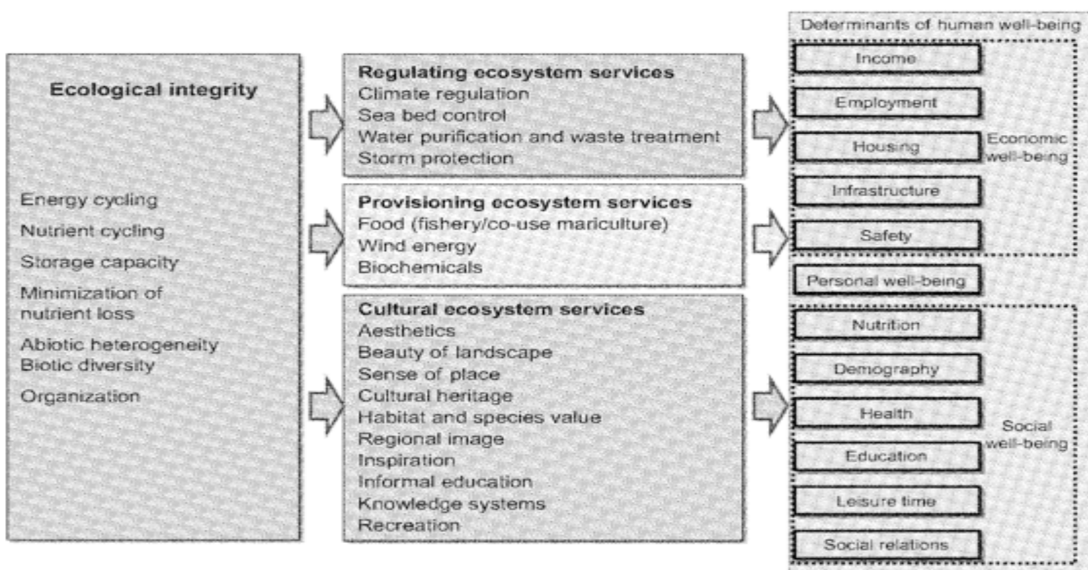


**Figure 4.** Diagram of ecosystem services and human wellbeing provisioned by ecological integrity

Conceptualization of the process by which biophysical structure and composition comprising ecological integrity provisions ecosystem services, which then provide human wellbeing. Source: Busch et al., 2011.

*1.2.1.2 Final Ecosystem Services*

Economic benefits are derived from the utilization of ecosystem services. No "one size fits all" definition of ecosystem services exists. Rather, definitions and typologies of ecosystem services are used for different heuristic and analytical purposes ( Costanza et al., 1997; Daily, 1997; de Groot et al., 2002). With respect to ecological production theory, ecosystem services are separated into those that are directly utilized to provide a benefit, and those that indirectly contribute to benefits delivery. The former are called *final ecosystem services*; the latter are called *intermediate ecosystem services*. Final ecosystem services can be defined as "the end-products of nature…directly enjoyed, consumed, or used to yield human well-being" (Boyd & Banzhaf, 2007, p. 619). This definition is designed to operationalize ecosystem services as a tool for stated-preference economic valuation and decision-making, a task discussed at great detail in recent literature (Boyd & Banzhaf, 2007; Boyd & Krupnick, 2009; Fisher et al., 2008; Fisher & Turner, 2009; Heal et al., 2005; Hein et al., 2006; Johnston & Russell, 2011; Ringold et al., 2009; USEPA, 2009; Wallace, 2007). Intermediate services can be defined as ecosystem organization, operation, functions, and outflows that contribute to the provision of final ecosystem services but are not directly utilized to produce a benefit (Fisher et al., 2008, 2009).

The above definition and classification of ecosystem services is adopted in the approach developed in this study. The definition of final ecosystem services above has four properties that relate to the approach (Johnston & Russell, 2011), which are discussed in turn below with reference to the approach:

1. Final ecosystem services provide a direct benefit (i.e. elicit a positive WTP if changes to all other benefits are held constant).

This property distinguishes them from benefits on one end and intermediate ecosystem services on the other. These distinctions are important for a number of reasons. The principal importance to an operationalizable approach is that identification of final ecosystem service provision must begin with a human beneficiary. From the analytical starting point of a beneficiary with a utility function and valued benefits, one can "back out" to the final services that provide those benefits (Johnston et al., 2010). By extension, backing out to the production of final ecosystem services identifies intermediate ecosystem services. This process is supported by the anthropocentric view on the ecosystem employed within the study of economics. All ecosystem services are therefore only a subset of all biophysical attributes of the ecosystem. In a value neutral world without beneficiaries, there are no ecosystem services.

This productive relationship is results in what is called *benefit dependence* (Fisher & Turner, 2008), and implies that is possible for the same ecological condition or process to represent both a final and intermediate ecosystem service. Benefit dependence is illustrated below in Figure 5 (adapted from Ringold et al., 2009). In this illustration, the endpoint of water quality may represent a final ecosystem service for a swimmer who wants to avoid contact with pollution (Individual 1). To a fisherman (Individual 2), however, clean water may combine with biological habitat to serve as intermediate ecosystem service into the final ecosystem service of rockfish abundance.

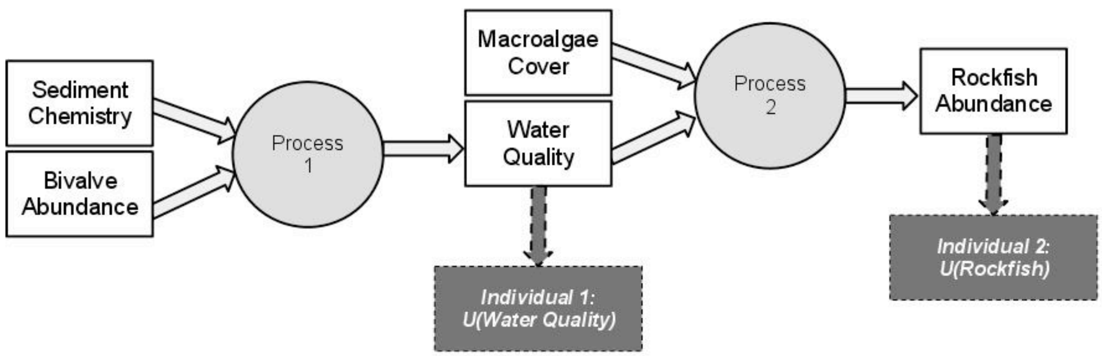


**Figure 5.** Diagram of benefit dependence and aquatic ecosystem services

Conceptual diagram of the flow of aquatic ecosystem components through natural processes to yield final and intermediate ecosystem services. Dark gray boxes depict ecosystem service beneficiaries. White boxes depict ecosystem services; those with dark gray arrows flowing from them are final services, while those with light gray arrows flowing from them are intermediate services. Note that "Water Quality" is both a final ecosystem service directly utilized by Individual 1 and an intermediate ecosystem service indirectly utilized via its contribution to the final service of "Rockfish Abundance" by Individual 2. Adapted from Ringold et al., 2009.

Furthermore, this property means that only benefits derived from final ecosystem services can be aggregated in economic accounting analyses. This restriction stems from the value of an intermediate ecosystem service as being implicit in the value of the final ecosystem service(s) it contributes to, and therefore aggregating values for both types of services would result in double-counting of benefits (Boyd & Banzhaf, 2007; Fisher et al., 2008; Fisher & Turner, 2009; Hein et al., 2006; Wallace, 2007). In the diagram above, therefore, the ecological endpoint of water quality is valued for its contribution to the utility of the swimmer only (i.e., its shadow value), and not for its indirect contribution to the rockfish abundance valued by the fisherman. Also, none of the other endpoints (e.g. sediment chemistry, macroalgae cover, etc.) are valued directly at all. As discussed in Section 1.2.4.1, these endpoints are therefore treated in the approach as part of the ecological production function, rather than the economic demand function (see Figure 3).

In addition to issues of double counting, however, economists agree that economic valuation methods—especially stated preference methods (see Section 1.2.3.3)—should not be applied to changes in intermediate ecosystem services due to potential bias from respondents' needing to understand the ecological relationships relating intermediate ecosystem services to welfare-relevant final ecosystem services (Barkmann et al., 2008; Johnston & Russell, 2011; Johnston et al., 2010; Kontogianni et al., 2010; Limburg et al., 2002). This topic is discussed in more detail in Section 1.2.3.3. Similarly, some economists do not think that valuation studies should be applied to what are called supporting services, and only to regulating services (see Millenium Ecosystem Assessment, 2006 and Section 1.2.3.3) if they provide a direct benefit (Hein et al., 2006). These considerations complicate the application of the approach to aspects such as biodiversity and other metrics of ecosystem processes and functions as ecosystem services. This topic is discussed in more detail in Section 1.2.3.4.

2. Final ecosystem services are biophysical components—ecological things or characteristics—in contrast to biophysical processes and functions, which are the interactions between components and therefore intermediate to the production of final ecosystem services.

This property implies that intermediate ecosystem services should be defined as processes and functions (the biological, chemical, and physical interactions between ecosystem components). This distinction is important to the approach insofar as ecosystem processes and functions are excluded from the economic demand function and incorporated into the ecological production function (see Figure 3). Note in Figure 5 that neither Process 1 nor Process 2 enter into a utility function.

3. Final ecosystem services are purely natural components in a state prior to combination with any human production.

This property further refines the distinction made by the second property and informs the treatment of different ecosystem aspects in the approach.

4. Final ecosystem services are quantities to be coupled with a price or value in order to estimate its contribution to human wellbeing.

This property is important to how the approach measures final ecosystem services. Specifically, the approach measures final ecosystems first, and then couples those quantities with a price or value in order to estimate its contribution to human wellbeing. Figure 3 illustrates this process as final ecosystem services entering an economic demand function to estimate ecosystem-derived benefits.

*1.2.1.3 Cultural Ecosystem Services*

The ecosystem service classification system employed in the approach is challenged by what some ecosystem service typologies call *cultural services* (Costanza et al., 1997; Millenium Ecosystem Assessment, 2006). Costanza et al. (1997) defines cultural services as values: "aesthetic, artistic, educational, spiritual and/or scientific values of ecosystems" (p. 254). The Millennium Ecosystem Assessment (2005) defines cultural values as benefits: "the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience" (p. 894). Economists criticize these two documents for conflating services, benefits, and values in general, and for grouping cultural ecosystem services as classes of benefits that do not fit well into other major classes of services (i.e. provisioning, regulating, supporting) (Chan et al., 2012). In fact, the catch-all nature of what are defined as cultural services illustrates the difficulty of classifying ecosystem services due to their multi-dimensional nature. As Chan et al. (2012) notes, "These values and benefits are so divergent from each other and so overlapping with the values associated with other 'master' categories of services (provisioning, regulating, supporting) (MA, 2005) that we can imagine no clean way to group these services without also including services that have been considered elsewhere" (p. 7). Similarly, benefits derived from final ecosystem services as defined in the approach (i.e. purely biophysical components prior to combination with other forms of capital) also overlap with benefits derived cultural services. From this standpoint, all ecosystem services produce a variety of benefits related to a variety of values.

Such complexity has two main implications for the approach developed in this study. First, it complicates any effort to map each service to only one type of benefit—a practice that is common among ecosystem service approaches and frameworks (Kareiva et al., 2011) but does not aid their operationalization. Second, and more importantly, the evaluation of multi-dimensional ecosystem services necessitates a multi-metric approach to valuation (Chan et al., 2012; Chee, 2004). This challenge is discussed more in Section 1.2.5.1.

### 1.2.2 Total Economic Value

From the perspective of an economic analysis, values can be classified according to a variety of typologies. A typology widely applied in natural resource economics that has implications for the approach developed in this study is *Total Economic Value* (TEV). TEV accounts for all measures of comparing environmental benefits with their opportunity costs and categorizes economic values according to their "tangibility" to individuals (Morton, 2000; Peterson & Swanson, 1987). Figure 6 (Hoagland et al., 1995) diagrams TEV for a coral reef environment. The approach developed in this study has the ability to include all of these values in its economic demand function. See Section 1.2.3 for a discussion of this topic.

#### 1.2.2.1 Use Value

The most tangible type of value is called *use value*, whose resultant benefits are derived from consumptive interaction (e.g. fishing) or nonconsumptive (e.g. surfing) interaction with the environment. Use value itself is broken into *direct*, *indirect*, and *option* use values. Direct use values are derived through consumptive and non-consumptive activities that are directly observable. Indirect use values are derived from the support and protection of activities holding direct use value (Heal et al., 2005), and are thus excluded from economic valuation (see Section 1.2.1.2). The approach developed in this study, however, does value ecosystem services that are traditionally considered intermediate when they provide direct value. See Section 1.2.2.3 below for a discussion of this topic. Option value is the value one places on the ability to use a resource in the future. The approach includes this value in the economic demand function insofar as it relates to direct use value, either through manifesting itself in observable behavior through actions to preserve a resource for future use (e.g. donations to conservation organizations) or through realized direct use in the future (e.g. visitation).

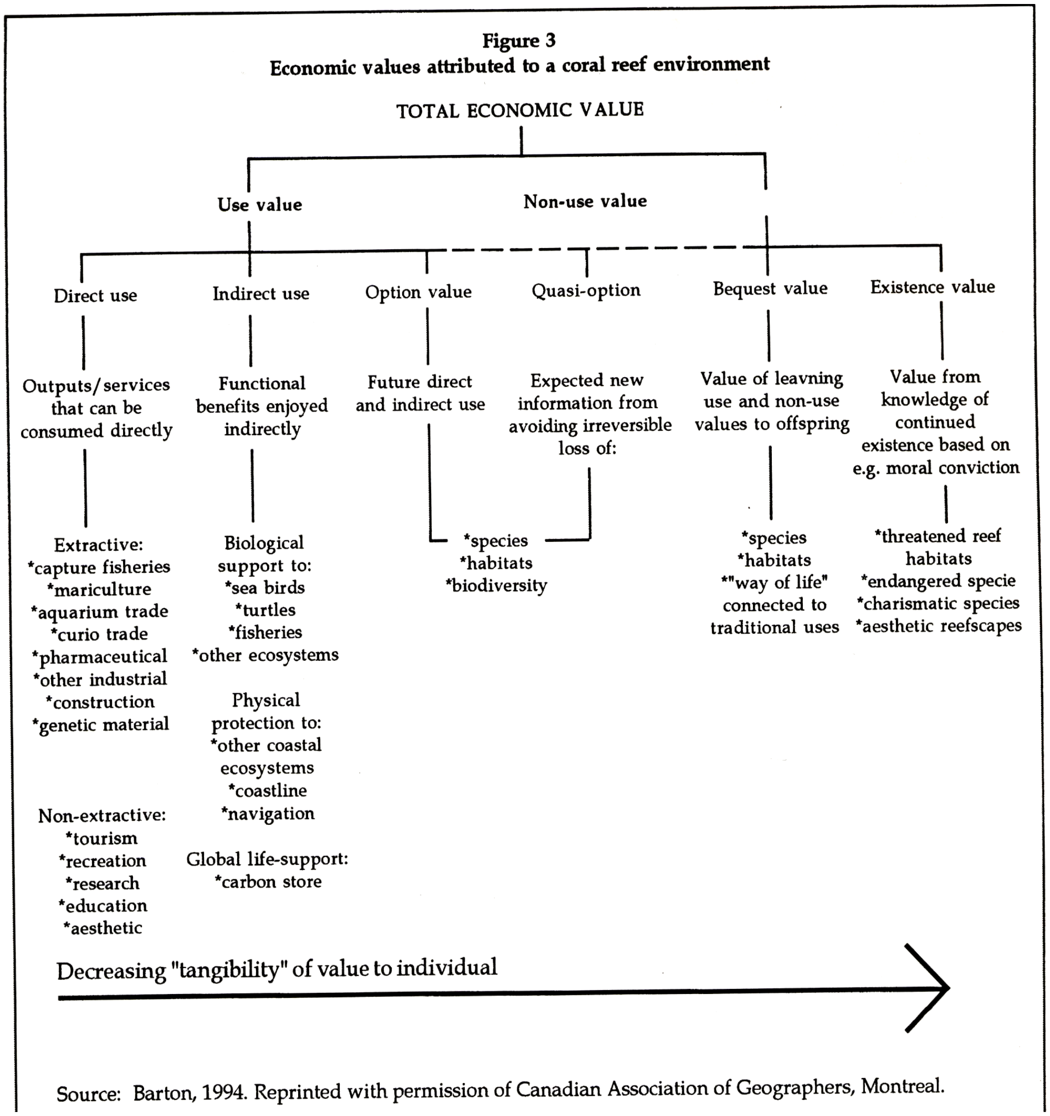


**Figure 6.** Diagram of Total Economic Value for a coral reef environment

Diagram of ecosystem components and processes categorized according to their provision of different values within the Total Economic Value framework. Note the arrow at the bottom illustrates the degree of "tangibility" of value to individuals. Source: Hoagland et al. (1995), citing Barton (1994).

### *1.2.2.2 Nonuse Value*

A less tangible type of value is called *nonuse value* (sometimes referred to as *passive use value*). The basic characteristic of nonuse value is that an individual can derive it without actually visiting or interacting with the resource. Measurement of nonuse value has become an important component of natural resource economics (Adamowicz et al., 1998; Hanley et al., 2003a), and nonuse value for wilderness has been found to outweigh other benefits included in a total economic value framework (Pate & Loomis, 1997). Furthermore, marine ecosystem services include nonuse components. There are three types of nonuse value (see Figure 6), which are best understood by considering the motives and cultural perspectives individuals attach to their valuing nature (Hein et al., 2006; Wallace, 2007). The approach developed in this study includes quasi-option values and bequest values in the economic demand function insofar as they relate to direct use value, either through manifesting itself in observable behavior through actions to preserve a resource for future use or use by another (e.g. donations to conservation organizations) or through realized direct use in the future (e.g. sustainable seafood markets).

#### *1.2.2.3 Existence Value*

The least tangible type of nonuse value is called *existence value*, and it is defined as the value from knowledge of continued existence of a resource (Krutilla, 1967). The motive for holding this type of value is often based on moral conviction regarding an inherent quality of the ecosystem, rather than its production of outputs (Hein et al., 2006). As described in Section 1.2.4.2, this type of utility function is precisely what challenges the production theoretic approach to ecosystem service valuation employed in the approach. In fact, it is debated whether economic valuation of existence values are valid and warrant inclusion in cost benefit analysis at all (Kopp, 1992).

Similarly, measures of existence value are often excluded from economic analyses of ecosystem services (Johnston et al., 2011) because this value is commonly assigned to intermediate services. However, it is possible for ecosystem processes and functions to directly provide a direct benefit via existence value (Boyd & Krupnick, 2009; Hein et al., 2006). For instance, individuals may directly value underlying biophysical processes for their inherent quality, rather than for their contribution to the production of final ecosystem services. The most debated example of these services is the provision of biodiversity, which scholars are currently seeking to value (Eppink & Vandenbergh, 2007). Another example is overall ecosystem condition (i.e., as measured according to a relatively undisturbed reference site) (Johnston et al., 2010), which has been shown to provide preservation benefits (Walsh & Loomis, 1984). Thus, the approach developed in this study allows for such processes and functions to be considered final ecosystem services and valued as such insofar as they provide existence value. A similar approach has been implemented empirically only once (Johnston et al., 2010), which makes the approach developed in this study relatively novel. The challenge of defining an ecosystem service that elicits pure existence value is discussed in Section 1.2.3.4.

### 1.2.3 Non-Market Valuation

The environment produces a range of goods and service flows to people. Some of these flows are linked directly to markets (e.g. timber as a factor of production), and therefore are measured in standardized units and valued in terms of price. Many environmental goods and services, however, are public goods with *nonexcludable* and *nonrival* (i.e., one person's using them does not come exclude or lesson another person's use) qualities. These qualities preclude these goods and services from being traded in markets and therefore lack market prices. This does not imply, however, that they lack value. Rather, their value must be derived through *nonmarket* valuation techniques.

Natural resource economics provides a range of methods to quantify the value of changes in nonmarket goods (Bockstael et al., 2000; EPA Science Advisory Board, 2009; Freeman, 2003), which are categorized generally as either *stated preference* and *revealed preference* (Freeman, 2003). The choice between these two nonmarket valuation techniques depends on targeted types of value within the TEV typology (see Section 1.2.2). Revealed preference techniques use economic behavior in markets to indirectly derive value for relevant nonmarket benefits. While revealed preference methods are generally accepted as more reliable, the required complementary relationship between market goods and the nonmarket good being valued does not always exist (Freeman, 2003). This relationship is by definition absent for nonuse values. Stated preference methods, on the other hand, can be used to elicit the full range of economic values (Freeman, 2003) and are frequently employed to assess use and nonuse values associated with changes in environmental resources (Aas et al., 2000; Bauer et al., 2004; Collins et al., 2005; Wessells, 2002). Stated preference methods rely on surveys for estimating value for nonmarket benefits. While stated preference methods can elicit a broader range of values than revealed preference methods, a number of potential sources of bias exist related to experimental design and elicitation method (Carson, 1991). Potential sources of bias relevant to this approach are discussed in Section 1.2.3.2.

#### *1.2.3.1 Commoditization*

Stated preference surveys derive value for environmentally derived benefits by packaging them as *simulated commodities* to which value can be attached—a process called *commoditization* (Boyd & Krupnick, 2009). The process of packaging such commodities is both pragmatic and philosophical, and relies on viewing nature as an entity from which one can extricate discrete features, qualities, and functions to which values can be attached. This is the anthropocentric and utilitarian nature of economic value. These commodities can represent anything of value, including commodities that hold nonuse value and therefore are not reflected in observable actions. Survey participants are then asked to make choices across the commodities, an analytical process that is discussed more in Section 1.2.5.2.

The process of commoditization itself involves two processes: *decomposition* of the ecosystem into environmental commodities that hold value (i.e., final ecosystem services) and *re-composition* of those commodities into items that are appropriate for use in stated preference surveys (Boyd & Krupnick, 2009). The process of decomposition can be operationalized in accordance with the productive relationships described in Section 1.2.4.1. The first step is to identify and define final ecosystem services by backing out from beneficiaries and their valued benefits. The next step is to characterize the ecological linkages underlying the provision of final ecosystem services (i.e. an ecological production function). Describing these linkages is not just an interdisciplinary step, but rather also informs a number of other analytic steps central to the approach developed in this study. First, characterizing the productive relationships between final ecosystem services helps avoid double counting, as well as address a number of cognitive issues associated with stated preference methods using complex environmental commodities. The latter issues are addressed in the following section. Second, a characterized ecological production function allows for the identification and description of the biophysical processes and functions necessary for indicating changes in final ecosystem service provision. This process is discussed in more depth in Section 1.2.4.1.

The process of re-composition then transforms this information into a format appropriate for use in stated preference surveys. This process involves *bundling* (i.e. consolidating) final ecosystem services into a smaller number of survey items. Bundling is necessary for a few reasons. First, the practical constraints of survey administration may not allow for each and every ecosystem service to be presented for valuation. This is the case with this study, which depicts the nearshore ecosystem in its entirety. For example, due to spatial and temporal fishery closures, the supply each species of commercially exploited fish may be considered a distinct ecosystem service. For the purposes of developing a survey, however, presenting each species individually would be redundant and therefore tiring to the respondent. Second, bundling allows for complementarities and substitution effects across final ecosystem services to be reflected in the survey items themselves (Boyd & Krupnick, 2009), which in turn communicates synergies or tradeoffs between final ecosystem services to survey respondents. Synergies are communicated in the consolidation of services into one survey item, and tradeoffs are communicated in the separation into different survey items—processes called, respectively, *undifferentiation* and *differentiation* in the phrasing of the survey items (Boyd & Krupnick, 2009). For example, while recreational divers may enjoy seeing both fish and marine mammals, the supply of each should be differentiated to reflect the predator-prey relationship between them that dictates that an increase in one comes at the expense of a decrease in another.

Characterizing ecological production functions is quite difficult and involves a range of uncertainties, including spatial and temporal nonlinearities (Barbier et al., 2008). A thorough ecological production function is not an objective of the approach developed in this study. Rather, the approach outlines a relatively coarse production function in order to identify complementarities and substitution effects, as well as biological and ecological indicators (hereafter referred to as *bioindicators*) of final ecosystem service provision (see Section 1.2.4.1). Complementarities and substitution effects are elucidated through analysis of two basic functional relationships: the productive relationship between final ecosystem services and the interaction between final ecosystem services. The first relationship is discussed in Section 1.2.1.2. The second type of functional relationship considered is the interaction between final ecosystem services, which include positive or negative, unidirectional or bidirectional, and opposite or same direction (Bennett et al. 2009). Describing these interactions helps avoid the consolidation of ecosystem services that interact or respond to drivers in opposite ways, as well as reveal correlations that may bias survey responses. This topic is discussed in more detail in Section 1.2.4.

#### *1.2.3.2 Potential Bias*

In order for survey items to produce unbiased and internally consistent estimates of welfare, their composition and presentation must communicate a specific level and type of information to the respondent. In short, valid stated preference methods require that survey respondents be provided information about the relevant ecological system and its provision of ecosystem services in a way that allows them to predict the effect of the expected ecological change on their welfare (Johnston et al., 2010). A number of factors must be considered in order for the approach to generate survey items that meet these criteria.

These factors involve the appropriate amount of information and the appropriate presentation of that information. With respect to the amount of information, the ecological information in survey item must be sufficiently well-defined. If the survey item does not present sufficient information about the ecological relationships underlying the provision of ecosystem services, respondents may assign value by filling in omitted ecological production function relationships that are relevant to their welfare. This process is called *embedding* (Kontogianni et al., 2010; Schiller et al., 2001). Embedding can be a source of biased welfare estimates because the ecological relationships underlying the production function model are complex and difficult for most survey respondents to understand (Kontogianni et al., 2010), and therefore the assumptions they use to fill in information will likely be incorrect, incomplete, or different from those quantified by ecologists.

With respect to presentation of information, survey items must communicate ecological information in a way that respondents understand and find meaningful (Ebert & Welsch, 2004). In order for respondents to understand a survey item, ecological information cannot be presented in language that is overly technical. While a survey item must correspond to ecological models in order to be understood by scientists and managers weighing policy outcomes, lay survey respondents are likely to only partially comprehend specialized language and concepts. This misunderstanding may bias welfare estimates because respondents are likely to under-appreciate the true value of the ecological processes the item represent and therefore incorrectly estimate their preferences related to changes in these processes (Kontogianni et al., 2010).

Furthermore, survey items must also communicate changes in environmental resources in a way they find meaningful (Ebert & Welsch, 2004), thus allowing them to estimate the effect on their utility. 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 (Carson et al., 2003). As stated by Schiller et al. (2001, p. 3), "effective communication of ecological [information] 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."

It should be noted that in order for the approach developed in this study to represent ecosystem processes and functions in a way that elicits existence value necessitates additional considerations to avoid these sources of bias (Johnston et al., 2010; USEPA, 2009). These considerations are discussed in more detail in Section 1.2.4.2. Similarly, the presentation of cultural ecosystem services involves additional considerations, which are discussed in Section 1.2.4.3.

### 1.2.4 Bioindicators of Final Ecosystem Services

The above potential sources of bias 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). The approach developed in this study adopts this method. Bioindicators can be defined as "components or variables inferring the state, conditions or attributes of the coastal system implied by a criterion" (Fontalvo-Herazo et al., 2007, p. 783). 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. Furthermore, the validity of welfare estimates depends on appropriately integrating bioindicators and economic information (Johnston et al., 2010).

Bioindicators used in marine assessments are numerous, and range from fish population dynamics to zooplankton densities and nitrogen levels (Fulton et al., 2005; Håkanson & Blenckner, 2008; Methratta & Link, 2006; Pelletier et al., 2008; Pomeroy et al., 2005; Rice, 2003; Rochet, 2003). In general, however, bioindicators do not necessarily correspond to commodities valued by any individuals of interest to any particular economic study. They can therefore correspond to final or intermediate ecosystem services, or processes or functions. In order for demand to be assessed empirically, however, bioindicators used in survey items must represent the final goods or services being demanded by users.

#### *1.2.4.1 Indicating Final Ecosystem Services*

A key component of the approach is therefore structurally linking bioindicators to the provision of final ecosystem services. This objective is addressed though the application of ecological production theory and functional ecology. Many ecosystem service classification systems that rely on ecological production theory refer to ecosystem structure, function, composition, and how those serve as biophysical inputs to ecosystem service delivery (Luisetti et al., 2011; Rounsevell et al., 2010b; Wallace, 2007; de Groot et al., 2002). These units can be connected to ecosystem service delivery using two concepts from functional ecology, which have recently been conceptually merged (Kontogianni et al., 2010).

The first concept is *Service Providing Units* (SPUs), which are defined as the "collection of individuals from a given species and their characteristics necessary to deliver an ecosystem service at the level desired by service beneficiaries" (Luck et al., 2009, p. 224). SPUs are concerned with the identification and quantification of the organisms and their characteristics that provide services and how changes in these organisms impact service provision. The second is *Ecosystem Service Providers* (ESPs), which can be defined as "those organisms, species, functional groups, populations or communities, or their trait attributes, that contribute to the provision of the specified ecosystem service" (Kremen, 2005, p. 469). This concept extends the concept of SPU by including species *functional traits* (i.e., species traits that interact with the surrounding environment), functional group, and interacting networks of organisms within each ecological organizational level (Noss, 1990). Coastal marine assemblages in California have been classified according to functional trait (Micheli & Halpern, 2005), but not within the context of welfare-relevant ecosystem services. Ecological organizational levels are divided into the following hierarchy: regional landscape, community/ecosystem, population, species, and genetic measurement units. This level identifies whether the type of bioindicator linked to ecosystem service delivery is measured at the population, functional group (Padilla & Allen, 2000) or community levels.

Like welfare-relevant ecosystem services, the relevant ESP/SPU units and characteristics which need quantifying can only be delineated if ecosystem service beneficiaries are identified first. Furthermore, some authors point out that the characteristics of ecosystem service beneficiaries are just as important to assessing ecosystem service provision as the characteristics of the underlying biology (Rounsevell et al., 2010a). Therefore, ESP/SPU units must also be identified via "backing out" from beneficiaries and related final ecosystem services (as well as criteria for the level and quality of their provision). This approach also structurally links welfare-relevant endpoints with measurable ecological units. These linkages are conceptually depicted in Figure 7 (adopted from Luck et al., 2009). One important note is that this process is useful in identifying ESPs/SPUs that produce valued ecosystem services, but efforts to value specific ESPs/SPUs have shown that beneficiaries undervalue the contribution of specific functional groups and traits to ecosystem service provision (Llorente-Garcia et al., 2011). This conclusion supports the practice of only valuing final ecosystem services, as well as relegating to biologists the task of quantifying the contribution of ESPs/SPUs to ecosystem services.

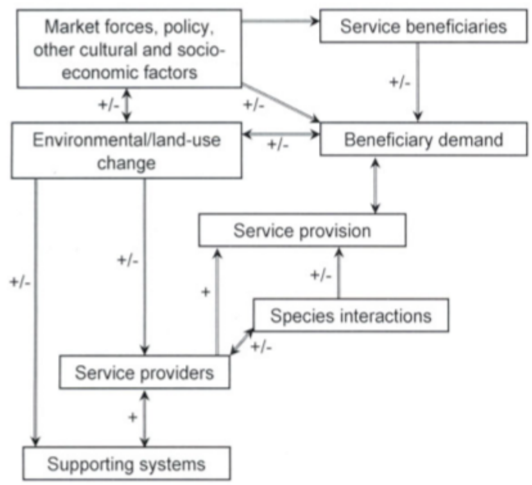


**Figure 7.** Diagram of the conceptual framework for ESP/SPU approach

Diagram of the possible (positive and negative) relationships between components and drivers of changes in ecosystem service provision. Drivers relevant to the ESP/SPU approach applied in this study are "Service beneficiaries," "Beneficiary demand," "Service provision," "Species interaction," and "Service providers." Source: Luck et al. (2009).

The approach developed in this study includes some of the steps in Figure 7 (e.g. linking "Service beneficiaries," "Beneficiary demand," "Service provision," "Species interaction," and "Service providers") in order to characterize bioindicators that indicate the provision of ecosystem services. The definition of ecosystem services used in this study specifies that final services are components that can be measured in a quantity (abundance, distribution, quality, or variability) that changes. The rate of change in this quantity is indicated by the rate at which ESPs /SPUs contribute to the provision of a final ecosystem service. This rate is derived from the *functional efficiency* of the functioning an ESP/SPU. Functional efficiencies can be measured as an ESP/SPU-specific property with a mean and variance, and can be correlated with measurable species traits to characterize the response and effect traits of a community (Larsen et al., 2005).

*1.2.4.2 Existence Value for Ecosystem Processes and Functions*

Existence value for ecosystem processes and functions enters into one's utility function differently from other values. Specifically, directly-valued ecosystem processes and functions like are often valued for their representation of the ecosystem on the whole rather than discrete parts of the whole, yet they inherently include all parts of the whole. Isolating existence value for ecosystem processes and functions therefore requires articulating a description that elicits only terminal value, rather than instrumental value with respect to the intermediate effect on other ecosystem services. Combining these demands, a survey item designed to elicit existence value for ecosystem processes and functions must at once (1) provide ecological information related to ecosystem processes and functions, yet (2) ensure that respondents interpret that information as corresponding exclusively to ecosystem processes and functions. In other words, it has to illustrate a sum that is greater than its parts (i.e. existence value for ecosystem processes and functions) by presenting the sum and parts that are not otherwise relevant to respondents' utility.

The ESP/SPU concept is still applied in the approach to indicate ecosystem processes and functions as an ecosystem service providing existence value. However, bioindicators are selected based on the additional criteria that they relate to only to those aspects of ecosystem processes and functions that elicit yet isolate existence value. In other words, they must indicate ecosystem components that fit one of the following criteria: 1) one estimates welfare of 0 for them alone, but welfare of >0 when indexed to represent ecosystem processes and functions (Johnston et al., 2010), or 2) represent systemic qualities of ecosystem processes and functions that provide terminal value (i.e. elicit WTP if changes to all other benefits are held constant).

#### *1.2.4.3 Cultural Ecosystem Services*

The approach also includes additional considerations related to what are traditionally called "cultural" ecosystem services (Millenium Ecosystem Assessment, 2006). As discussed in Section 1.2.1.3, many cultural services are not strictly biophysical components, but rather a multi-metric function with biological, social, economic, and social derivatives realized via a combination of biological and human capital. This multi-metric nature must be considered when indicating the provision of cultural services, as well as presenting those survey items in stated preference surveys. Specifically, their indication must include socioeconomic measurements in addition to any bioindicators identified using the SPU/ESP approach.

### 1.2.5 Analyzing Tradeoffs of Ecosystem Services

Economists measure values in comparative terms, which are observed through measuring individuals' preferences or marginal willingness to trade one good or service—real or simulated—for another. Natural resource allocation invariably involves such trades in the form of choices across planning scenarios. Even conservation, which does not alter the resource, represents a choice not to alter the resource for productive use. This and any other resource management decision therefore involve *tradeoffs* between alternatives. Since different resource allocations and impacts translate into different flows of ecosystem services, all policy decisions imply tradeoffs across the provision of ecosystem service types and levels of those services in space and time, which in turn involve trading off values. While a certain level and pattern of provision may represent an optimal choice across alternatives, this choice is based on pre-existing objectives and criteria that themselves imply tradeoffs.

#### *1.2.5.1 Multi-Criteria Decision Analysis*

In order to meet the objective of allowing stakeholders to make tradeoffs between multi-dimensional ecosystem services, the approach developed in this study employs a multi-metric approach. Multi-metric approaches are collectively referred to as multi-criteria decision analysis (MCDA) (Hajkowicz, 2007; Kiker et al., 2005) and commonly advocated for ecosystem service valuation (Chan et al., 2012; Chee, 2004; Gatto & De Leo, 2000; Norton & Noonan, 2007; Spash, 2008; Spash, 2008). MCDA methods are oriented to the multi-dimensional character of many natural resource management problems and are designed to overcome the problems of multiple objectives, incommensurate units, the need to consider both qualitative and quantitative data and the need to incorporate stakeholder knowledge and preferences (Chee, 2004). These tools are inherently capable of integrating biological, social and economic data. They are ideal for assisting evaluation in data-poor situations such as ecosystem services (Fisher et al., 2009).

#### *1.2.5.2 Weight Solicitation*

In order to quantify tradeoffs between ecosystem services, *weights* must be specified (Yoe, 2002). A weight can be defined as “a measure of the relative importance of a criterion as judged by the decision maker” (Yoe, 2002, p. 52). Weights are applied or derived through a subjective valuation exercise on the part of the decision-maker. Since putting values on things implies a ranking, the output is a set of values that indicate the relative importance of each criterion. Stated preference surveys derive respondents’ weights by scaling answers according to a metric of preference (Brown 2003), such as monetary amounts, choices, or ratings. Metrics of measurement can be measured within a stated preference context using *ordinal, cardinal* or *ratio* scales. Ordinal methods ask respondents to order items without concern for the degree of difference between items. Cardinal scales linearly transform ordinal ranks so that resulting weights sum to one. Survey questions measuring ratio scales ask respondents to provide or choose a numerical amount that indicates the value they place on an item.

One type method advocated to derive weights for multidimensional criteria tradeoffs is the method of *paired comparisons* (Chan et al., 2012; Chuenpagdee et al., 2010; Hanley et al., 1998; Naidoo & Adamowicz, 2005). A paired comparison presents two items and asks the respondents to choose the one they prefer. Each pair results in a binary choice that is assumed to be independent of all other choices. The full set of choices yields a *preference score* for each item, which is the number of times the respondent prefers an item to other items in a set. The response matrices of all respondents in the sample can be summed to provide a frequency matrix for the sample, which gives the *aggregate preference scores* (or the *scale values*) for the sample. Scale values show the number of times each item was chosen across all paired comparisons made by respondents. This value indicates the ordinal position of the items, as well as approximates an interval scale measure of preference, revealing the sizes of the intervals between items (Brown 2003).

The approach developed in this study employs the paired comparison method. Resulting weights are derived from respondents' expressing relative preferences for changes to ecosystem goods and services, rather than for levels of ecosystem services. There are a number of reasons the approach is designed to derive relative value for ecosystem services on a cardinal scale rather than a ratio scale. First, survey items of ecosystem services that are complex or unfamiliar and stakeholders may difficulty understanding internal quantities and gradients of quality, let alone relate changes along those dimensions to changes in their own welfare. Application of a ratio scale therefore might generate error and biased responses (Johnston et al., 2010). This feature of ecosystem services further suggests that valuation in the form of WTP would be inappropriate because the mental search to compare complex environmental services to goods that they actually pay for will not be thorough, context-free, or unbiased (Johnston et al. 2011).

# CHAPTER 2

# DEVELOPMENT AND IMPLEMENTATION OF AN APPROACH TO ANALYZE TRADEOFFS ACROSS MARINE ECOSYSTEM SERVICES

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## 2.1 INTRODUCTION

Chapter 1 detailed the policy context and theoretical foundations of approach for evaluating ecosystem tradeoffs developed and tested in this study. This chapter has two main parts. The first part details application of information from Chapter 1 to the development of the approach with respect to a primary analytic objective: generating survey items of marine ecosystem services that can be used to evaluate tradeoffs associated with marine spatial planning (MSP) in Oregon. The second part documents an implementation study of the approach to the process and communities involved in siting marine reserves in Oregon.

### 2.1.1. Policies and Practices Guiding the Approach

This study was principally motivated by the policy of Oregon Sea Grant and the State of Oregon's Department of Fish and Wildlife to evaluate the ecological and socioeconomic tradeoffs associated with emerging nearshore management actions. In accordance with regional (West Coast Governors Agreement on Ocean Health, 2008) and national guidelines (White House Council on Environmental Quality, 2010), nearshore management actions in Oregon is grounded in the principles of ecosystem-based management (EBM). Nearshore management actions include all MSP and the establishment of MPAs, the latter of which provides the context for the implementation study described in this chapter. The overarching design criteria for the approach therefore stem from nearshore management policy in Oregon, as well as the principles and practices of EBM and MSP.

As a tool for implementation of EBM, MSP must meet a wide range of procedural and outcome-based objectives. The state of Oregon was interested in meeting two of those objectives: the conservation of provision of ecosystem services (McLeod & Lubchenco, 2005), and the consideration of common social values and preferences within a scientific understanding of the ecosystem (Crowder & Norse, 2008). The approach is designed to meet the first objective through the measurement and valuation of marine ecosystem services, which in turn carries three criteria provided by Nahlik et al. (2012): quantification and communication of the contribution of ecosystem services to human well-being; the evaluation of trade-offs between ecosystem services and between ecosystem services and "services generated through human efforts" (p. 28); and inclusion of the value of ecosystem services in the relevant resource management decision making process. The approach is designed to meet the second objective of the State of Oregon through engagement of the local stakeholder community and structured integration of ecological and economic analysis. The specific methods employed in the approach to achieve these objectives are detailed in this chapter.

### 2.1.2. Objectives of the Approach

In order to meet the policy objectives above, the principal objective of the approach is to generate survey items that can be used to evaluate ecosystem service tradeoffs associated with MSP in Oregon. The criteria for this objective are provided by the theory and practice of natural resource economics, in particular stated preference methods of economic valuation. As discussed in Section 1.2.4, the valid application of stated preference methods to the valuation of ecosystem services requires appropriately integrating bioindicators and economic information (Johnston et al., 2010; Kontogianni et al., 2010). Furthermore, survey items must meet three theoretical requirements of nonmarket economic valuation techniques. The first requirement is that survey items link attributes of ecological models and ecosystem services that provide utility to respondents. This topic is discussed in Section 1.2.4. The second requirement is that survey items be appropriate for economic valuation in that they are unambiguous and quantitatively commensurate with neoclassical utility models used for valuation. This topic is discussed in Section 1.2.3.3. The third requirement is that survey items provide information that is meaningful, comprehensive, and comprehensible to survey respondents. This topic is discussed in Section 1.2.3.3. Lastly, survey items must be structured in order to solicit relative preference weights through a tradeoff exercise. This topic is discussed in Section 1.2.5.

## 2.2 APPROACH DEVELOPMENT

As discussed in Chapter 1, ecological production theory serves as the conceptual and operational foundation for the approach. Specifically, it characterizes the process of benefits delivery, the typology of ecosystem services used, the method of identifying ecosystem services, their depiction within stated preference surveys, the description of productive relationships underlying their provision, and their indication. Each of these topics is discussed in turn with regard to their bearing on design of the approach.

Ecological production theory links the provision of ecosystem services to the delivery of valued benefits according to Figure 8 (Adapted from Wainger & Boyd, 2009, p. 102). The individual components of this conceptual framework and the vocabulary used to describe them are each discussed in Chapter 1.

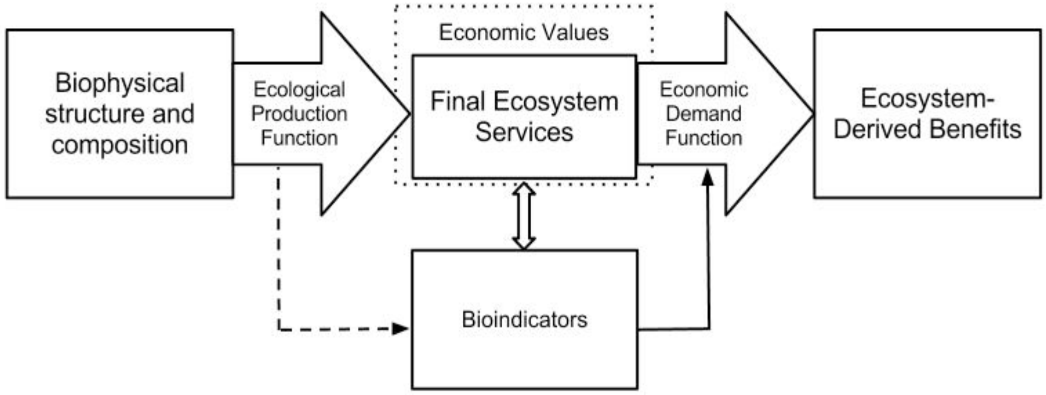


**Figure 8.** Diagram of the conceptual framework for economic valuation of ecosystem services

Diagram of a systems-based conceptualization of the process by which biophysical structure and composition translates into the delivery of valued benefits. Block arrows represent functions to be calculated. Blocks represent inputs and outputs of functions. Solid line arrows depict the process of identifying and utilizing bioindicators in valuation. Adapted from Wainger & Boyd, 2009, p. 102.

The principal goal of this study is to operationalize the conceptual framework depicted above. The principal objective of the approach developed in this chapter, however, is more limited. Specifically, the principal objective of the approach is to generate survey items that can be used to analyze tradeoffs across marine ecosystem services. Therefore, the approach operationalizes elements prior to (left of) the economic demand function in Figure 8. The approach developed in this study is illustrated in Figure 9 below. Note that the approach can be generally understood as reversing the relevant arrows in Figure 8. The principal reason for this is that a conceptual depiction of benefits delivery is seen from the perspective of ecological production, while the operational process of characterizing ecological production must “back out” from the analytical starting point of an ecosystem-derived benefit. See Sections 1.2.1.2 and 1.2.4.1 for discussions of this topic. The rest of this section discusses each of the components in the conceptual framework above with regard to the approach developed in this study.

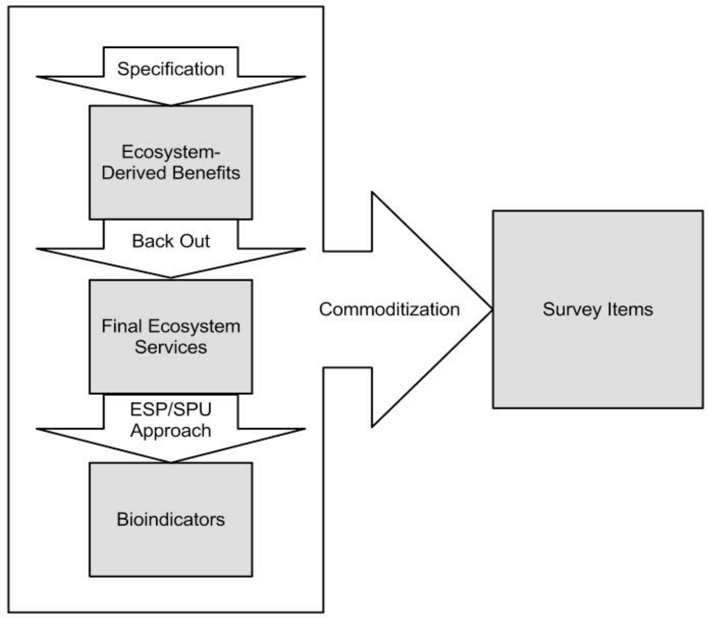


**Figure 9.** Diagram of the operational approach for generating survey items

Diagram of a community-based approach for integrating ecological and economic information in order to generate survey items that can be used to evaluate tradeoffs across marine ecosystem services. Objectives of the approach are to generate the components illustrated with boxes. Methods applied in the approach to generate those components are illustrated with arrows.

The following sections are organized by components according to the order in which they are generated by the operational approach in Figure 9.

### 2.2.1 Final Ecosystem Services

Central to the approach is an ecosystem service definition and classification system that is appropriate for measuring, valuing, and communicating ecosystem services. With this objective, the definition of ecosystem services used in the frame work is "…"components of nature, directly enjoyed, consumed, or used to yield human well-being" (Boyd & Banzhaf, 2007). This definition is refined by adding that final ecosystem services are purely natural components in a state prior to combination with any human production (Johnston & Russell, 2011). Within the parlance of ecological production theory, this definition defines what are called *final ecosystem services* as opposed to *intermediate ecosystem services*, which combine to produce final ecosystem services but are not themselves valued in the approach. See Section 1.2.1.2 for a discussion of the implications of this definition.

The definition used in the approach functions within ecological production theory, which itself provides a beneficiary-based classification system appropriate for the objectives of measuring, valuing, and communicating ecosystem services. As Nahlik et al. (2012) point out, the definition and classification system have a number of analytical advantages. First, they minimize ambiguity and promote repeatable identification of ecosystem services. Second, they avoid double-counting. Third, they encourage interdisciplinary research by integrating environmental and economic features. Fourth, identified ecosystem services are by definition understood by beneficiaries, which can include the public and broader stakeholder community.

The approach details the process of operationalizing the definition and classification system with respect to the objectives of measuring, valuing, and communicating ecosystem services. The first step toward these objectives is to identify ecosystem services. As discussed in Section 1.2.1.2, final ecosystem services by definition must be characterized by a utility function for an ecosystem services beneficiary (Haines-Young & Potschin, 2010; Rounsevell et al., 2010). From the analytical starting point of ecosystem-derived benefits that enter into this utility function, one can "back out" to identify final ecosystem services (Johnston et al., 2010) (see Figure 9).

Backing out is conceptually simple. The first step is for an ecosystem service beneficiary to identify an ecosystem-derived benefit, which can be generally defined as "valued goods and experiences" derived from environmental components (Chan et al., 2012, p. 3). This definition is further qualified by Fisher et al. (2008) by noting that benefits have a "direct impact on human welfare" and "are typically generated by ecosystem services in combination with other forms of capital" (p. 2052). See Section 1.2.1.1 for a discussion of this definition. The second step of backing out is for the ecosystem service beneficiary to identify final ecosystem services that provide the identified benefit. While perhaps a simple process for one beneficiary, the approach developed in this study is community-based and thus identifies final ecosystem services for a group of stakeholders.

### 2.2.2 Bioindicators

Identifying bioindicators using the ESP/SPU approach involves a process similar to that used to identify final ecosystem services via backing out from ecosystem-derived benefits. This process includes four steps:

1. Identify the *ecosystem service providers* (ESPs) and *service providing units* (SPUs) that provide that final service. Section 1.2.4.1 defines these terms and provides attendant references to the development of these concepts.
2. Identify the functional units that categorize the identified ESPs/SPUs.
3. Identify the *functions* and *functional traits* that relate the ESPs/SPUs to their provision of the relevant final ecosystem service. Section 1.2.4.1 defines these terms and provides attendant references to the development of these concepts.
4. Identify the *functional efficiency* metrics that measure the rate at which the functions and functional traits of the identified ESPs/SPUs contribute to the provision the relevant final ecosystem service. Section 1.2.4.1 of defines these terms and provides attendant references to the development of these concepts.

It should be noted that this series of steps corresponds to the ecological production function included in Figure 8. The term ecological production function is a generalized term, however, and can be applied to quantification of a range of ecological dynamics underlying the provision of ecosystem services (Sanchirico & Mumby, 2009). The ESP/SPU Approach applied in the approach can be considered a specific applied ecological production function with the single objective of identifying bioindicators of final ecosystem service provision. As noted in Section 1.2.4.1, this application is relatively rudimentary as a result of the relatively narrow objectives of the approach at this point in development. Nevertheless, the approach allows for development of a more sophisticated ecological production function (Kremen, 2005; Kremen & Ostfeld, 2005).

### 2.2.3 Survey Items

Since many ecosystem services are not already packaged and traded directly in a market, their direct valuation in stated preference methods first requires their packaging as *simulated commodities* to which value can be attached—a process called *commoditization* (Boyd and Krupnick 2009). The process of defining and packaging such commodities involves two steps: decomposing the ecosystem into directly valued ecosystem services, followed by recomposing those services into commodities that are appropriate for use in stated preference surveys (Boyd & Krupnick, 2009). Decomposition is carried out through the processes described above, the final products of which are the approach components of ecosystem-derived benefits, related final ecosystem services, and related bioindicators.

Recomposition involves consolidating these components into a set of survey items. This process is desired for a number of reasons related to established survey methodology (see Section 1.2.3.2). The objective of recomposition is to generate survey items that meet the criteria listed in Section 2.2.2, as well as the additional criteria for survey items representing ecosystem services that elicit existence value listed in Section 1.2.4.2. The objective of recomposition is to determine the appropriate amount of information provided in survey items (Section 1.2.3.2), language used to present that information (Section 1.2.3.2), and structure of the survey item systems (Section 1.2.5). Both practical and theoretical criteria define what is considered 'appropriate.' The practical criteria reflect the principles and practices of EBM and other factors specific to each application. The process of re-composition employed in the implementation study used the methods of both expert opinion and focus groups, and is documented in Section 2. 4.

The theoretical criteria for survey items generated by the approach are provided by stated preference valuation research. Meeting these criteria involves four steps. The first step is to identify complementarity and substitution effects across final ecosystem services by an analysis of the productive relationships between services (see Section 1.3.2.2). Identifying these principles facilitates the identification of potential synergies or trade-offs between ecosystem services, which should be reflected in either their consolidation into one survey item or separation into different survey items—processes called, respectively, *undifferentiation* and *differentiation* in the phrasing of the survey items (Boyd & Krupnick, 2009). Implementation of this step is documented in Section 2.4. The second step is to refine the degree of differentiation in survey items according to the utility functions of stakeholders. Information on the utility functions of stakeholders can be acquired through any number of methods. The implementation of this step of the approach employs the method of stakeholder focus groups and is documented in Section 2.4.

The third step of recomposition is to determine the structure of each survey item. In addition to the structure of the survey item set and system, each item must be designed in order to generate data appropriate for one or more choice modeling approaches. The implementation of the approach structures survey items with the minimum objective of deriving preference weights on a cardinal scale via the method of paired comparisons. This choice is discussed in Section 1.2.5.2 and implementation study items are presented in Table 4. As discussed in Section 2.5.4, however, the implementation study survey items also provide a foundation for development of an attribute-based method similar to that developed by Johnston et al. (2011).

The fourth step of re-composition is to further refine survey item content, form, and structure with the objective of meeting the criteria listed in Section 2.1.3. Meeting these criteria involves three considerations. First, survey items must be designed to minimize potential sources of bias in stated-preference methods (discussed in Section 1.2.3.3). Second, survey items must be designed to reflect the multi-dimensional nature of ecosystem services (discussed in Section 1.2.1.3). Third, additional criteria must be considered when designing survey items that elicit existence value (discussed in Section 1.2.4.2). The implementation study used the methods of expert opinion and focus groups to complete this step and is documented in Section 2.4.4.

## 2.3 IMPLEMENTATION STUDY OBJECTIVES

This section provides the objectives of the implementation study of the approach developed in Section 2.2. The approach is designed to be broadly applicable to any MSP action, and is flexible in design. The primary goal of this implementation study is to test the approach for its ability to generate survey items that meet the following theoretical requirements: link attributes of ecological models and ecosystem services that provide utility to respondents; be appropriate for economic valuation in that they are unambiguous and quantitatively commensurate with neoclassical utility models used for valuation; and provide information that is meaningful, comprehensive, and comprehensible to survey respondents.

In accordance with Figure 9 and the corresponding steps in Section 2.2, implementation of the approach has four operational objectives: 1) Identify final ecosystem services valued by coastal resource stakeholders in Oregon; 2) Define structural linkages between final ecosystem services and bioindicators of their provision; 3) Develop survey items of final ecosystem services appropriate for stated-preference valuation; and 4) Test survey items for their ability to meet stated criteria. The effort to meet these objectives is addressed in turn in the following sections.

## 2.4 IMPLEMENTATION STUDY METHODS

This section provides the methods used to implement the approach developed in Section 2.2. This section is divided according to the four objectives above.

### 2.4.1 Objective 1: Identify final ecosystem services valued by coastal resource stakeholders in Oregon

In order to identify final ecosystem services provided by the nearshore marine environment in Oregon, I organized stakeholder focus groups in the two coastal communities where pilot marine reserves are located (i.e., Port Orford and Newport/Depoe Bay), as well as in a non-coastal location (Corvallis, Oregon). The method of stakeholder focus groups was chosen with the goal of engaging local stakeholders in the MSP process on a community-level. Stakeholder focus groups had been used previously to conduct an economic valuation of marine resources in Oregon (Hesselgrave et al., 2011). Furthermore, focus groups provide a forum for public discussion and education (Wilson & Howarth, 2002) on the topic of ecosystem services, which researchers and State resource managers believed was a valuable contribution. An alternative method of identifying ecosystem services that complements focus groups is conducting individual interviews (Wilson & Howarth, 2002).

Two meetings were held in each location. Participants were recruited to participate in focus groups based on their known activity in the ocean planning process in their community, as well as their affiliation to the eight stakeholder categories stipulated in Oregon House Bill 3013: local government, recreational fishing industry, commercial fishing industry, nonfishing industry, recreationalists, conservation, coastal watershed councils, and relevant marine and avian scientists. This sampling method was not intended to generate a representative sample. Rather, participants were recruited with the goals of further engaging active stakeholders and ensuring even stakeholder group representation.

Questions presented focus group participants during the first meeting were as follows:

1. “How do you benefit from your local marine environment?”

So that participants could answer this question, I provided them the following operational definition of a benefit was adapted from Fisher (2008): *Something that has a direct impact on your welfare.* Additional information refining the definition of a benefit (e.g. that it can be a thing or a feeling, see Section 1.2.1.1) was also provided participants so that they fully understood and could identify benefits.

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. With this requirement in mind, the second question presented focus group participants during the first meeting was:

2. What ecosystem services directly provide these benefits?

So that participants could answer this question, I provided them 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.*

Note that this definition is not the same as the one presented in Section 1.2.1.2 as being central to the approach. This is because it was my opinion that that definition was too technical to present focus group participants. Through facilitation, however, I ensured that the information identified by participants met the technical definition of an ecosystem service and all of its principles.

3. How do you expect these benefits and ecosystem services to change as a result of marine reserves in Oregon?

While this information was not directly incorporated into this study, it provided me an opportunity to understand which benefits and services were most relevant to MSP.

Additionally, I recorded 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 commoditization (Objectives 3 and 4).

#### *2.4.1.1 Whole system processes as a final ecosystem service*

The structure of questions employed in the first focus groups was designed to identify final ecosystem services via "backing out" from ecosystem-derived benefits. However, participants in the first focus groups at times resisted the task of extricating specific ecosystem services with terminal value in favor of discussing the importance they place on the local marine ecosystem as an indivisible system. While this tendency could be seen as peripheral to the task at hand, I chose to try to capture and incorporate the resulting information into the approach.

The first step was to try to articulate what participants had trouble articulating themselves. Upon reviewing the proceedings of the first focus groups, I found that the central concern of participants to was that they know the natural processes underlying the whole ecosystem were in good condition. This sentiment had three facets. The first was that participants were interested in the processes underlying the whole system as something independent from their own lives. The second is that participants were not interested in understanding the intricacies of the processes themselves. The third facet is that participants valued the condition of the collective processes—of the system as a whole. This sentiment in fact was an expression of existence value (i.e., the value from knowledge of continued existence of a resource, as defined by Krutilla (1967)) for the ecological processes that make up the whole marine ecosystem. As described in Section 1.2.2.3, the motive for holding this type of value is often based on moral conviction regarding an inherent quality of the ecosystem, rather than its production of outputs (Hein et al., 2006). This too was the case with focus group participants.

The next step was to allow stakeholders to provide their own definition for this sentiment in a way that was comparable with other ecosystem services identified during focus groups. In order to do this, I organized an additional focus group in Corvallis, Oregon, that I dedicated to characterizing existence value for whole system processes. I recruited participants via the same sampling method as previous focus groups (i.e. based on their known activity in the ocean planning process in their community, as well as their affiliation to the eight stakeholder categories stipulated in Oregon House Bill 3013). Again, this sampling method was not intended to generate a representative sample. Rather, participants were recruited with the goals of further engaging active stakeholders and ensuring even stakeholder group representation.

Questions developed for the first meeting of the focus group were aimed at generating two types of data: 1) A definition of whole system processes that provides a psychological benefit holding existence value, and; 2) Related bioindicators that meet the general criteria (see Section 2.1.3) and additional criteria for bioindicators representing ecosystem services that elicit existence value (i.e., elicit WTP of 0 alone, but WTP of >0 when indexed to represent whole system processes, or represent systemic qualities that elicit WTP if changes to all other benefits are held constant). Additionally, general language describing participants' values, goals, and criteria related to their local marine environment and marine reserve were recorded in order to inform commoditization.

First, I employed a thought experiment to elicit the first type of data, a definition of whole system processes that provides a psychological benefit holding existence value. I asked participants to imagine a pristine area of the Amazon, then succinctly describe the ecosystem. The analogy of the Amazon was chosen for two reasons. First, describing a distant environment that participants likely never have, nor never will, visit personally facilitated the isolation of existence value. Second, many people are familiar enough with the Amazon environment through various media to describe its ecosystem vividly. Second, I built on the Amazon illustration in order to identify appropriate bioindicators. Specifically, participants were asked to list descriptors of the ecosystem in the form of characteristics, qualities, or dynamics with respect to the criterion that measures represent systemic qualities that provide a direct benefit. This and other information delineated participants' understanding of the complexities of ecosystem processes, which informed the criterion that measures elicit a WTP of 0 alone, but WTP when indexed to represent whole system processes.

### 2.4.2 Objective 2: Define structural linkages between bioindicators and final ecosystem services

I completed this objective by consulting academic literature. For each final ecosystem service identified from the first focus group meeting, I identified related bioindicators through the ESP/SPU approach (see Figure 7 and Section 2.2.2). Specifically, for each final ecosystem service, I identified the following information: ESPs/SPUs, functional units, functions and functional traits, and efficiency measures. A sample of this process is described in Table 1. The first step to applying the ESP/SPU approach was to generally describe the productive linkages between services and ecosystem composition, structure, processes and functions. In order to complete this step, I consulted literature on marine ecosystem service provision (Atkins et al., 2011; Elmqvist et al., 2010; Fletcher et al., 2011; Townsend et al., 2011; de Groot et al., 2010, 2002). While many of these studies addressed the provision of ecosystem services in a generic sense, they still provided valuable guides.

**Table 1.** Example of the ESP/SPU approach for one final ecosystem service

| Final Ecosystem Service | Ecosystem Service Providers | Functional Units | Functions/Functional Traits | Efficiency Measures (Bioindicators)[2] |
|---|---|---|---|---|
| Production of non-harvested fish biomass[1] | Non-harvested fish of size large enough to see easily | Species | Production of visible individuals | Growth of non-harvested larger/conspicuous demersal fish |
| | | Species | Production of visible individuals | Growth of non-harvested forage fish |
| | | Population | Production of visible individuals | Average size (length) of non-harvested larger/conspicuous demersal fish |
| | | Population | Production of visible individuals | Average size (length) of non-harvested forage fish |
| | | Population | Production of visible individuals | Abundance (count) of non-harvested larger/conspicuous demersal fish |
| | | Population | Production of visible individuals | Abundance (count) of non-harvested forage fish |
| | | Community | Production of visible individuals | Density (#individuals/100m$^2$) of non-harvested larger/conspicuous demersal fish |
| | | Community | Production of visible individuals | Density (#individuals/100m$^2$) of non-harvested forage fish |
| | | Community | Production of popular individuals | Biomass accumulation among sedentary focal species community assemblages |

Note:
[1]This final ecosystem provides the benefit of "Viewing of wildlife," which relates to the functional importance of visibility.
[2]Measured as a rate (e.g. growth rate, rate of increase of average size, etc.)

Next, in order to identify ESPs/SPUs, I consulted literature on the provision of ecosystem services by the different classes of ESPs/SPUs. Studies of this sort are limited, but include analysis of organisms such as fish (Holmlund & Hammer, 2004; Holmlund & Hammer, 1999), soil invertebrates (Lavelle et al., 2006), oysters (Coen et al., 2007), macrophytes (Engelhardt & Ritchie, 2001), and birds (Whelan et al., 2008). Similar analyses were done on other ecosystem levels, such as sedimentary communities (Snelgrove, 1997, 1999; Weslawski & Snelgrove, 2004), populations (Luck et al., 2003), and coral reef ecosystems (Moberg & Folke, 1999). These study results were related to the specifics of the implementation study by consulting a literature review on the impacts of temperate marine reserves (Heppell et al., 2008). I could not find literature on ecosystem services provided by functional groups or guilds, but consulted a study that identified marine functional groups  (Micheli & Halpern, 2005). The most informative body of literature was that on ecosystem functioning and functional ecology (Balvanera et al., 2006; De Bello et al., 2010; Kremen & Ostfeld, 2005; Naeem et al., 2009). This literature was also used to identify the functioning and functioning traits of various units. In order to classify ESPs/SPUs according to their functional unit, literature on the levels of biodiversity and ecological organization were consulted (Noss, 1990).

The final version of bioindicators linked the provision of ecosystem services were identified by defining the functional efficiency measures of functions and functional traits. Literature used to support this effort addressed bioindicators measuring the effects of fishing (Fulton et al., 2005; Methratta & Link, 2006; Rochet, 2003), indicators of ecological integrity and health (Burkhard et al., 2011; Karr, 1991; Leo, 1997; Müller, 2000; Parrish et al., 2003; Rice, 2003), indicators of biodiversity loss (Eppink & Vandenbergh, 2007), habitat classification (Tillin et al., indicators for ecosystem-based fisheries management (Babcock et al., 2005; Link, 2005), trophodynamics (Cury et al., 2005), coastal management (Håkanson & Blenckner, 2008), and marine reserve and protected area design and performance (Botsford et al., 2008; Hilborn et al., 2004; Pelletier et al., 2008; Pomeroy et al., 2005). These indicators were modified according to existing biological monitoring of the marine reserves in Oregon by the Oregon Department of Fish and Wildlife and Oregon State University (Oregon Department of Fish and Wildlife, 2012).

### 2.4.3 Objective 3: Develop survey items of ecosystem services for stated preference valuation

As discussed in Section 2.2.3, survey items are generated through a process of commoditization, which involves two steps: decomposition and recomposition. Objectives 1 and 2 comprised the step of decomposition, the output components of which are sets of ecosystem-derived benefits, related final ecosystem services, and related bioindicators. The objective of recomposition is to generate survey items that include these output components and meet the criteria listed in Section 2.1.2, as well as the additional criteria for survey items representing ecosystem services that elicit existence value. Meeting these criteria involves four steps. The first three comprise Objective 3 and the fourth comprises Objective 4.

The first step is to identify complementarity and substitution effects across final ecosystem services by an analysis of two basic functional relationships: the productive relationship between final ecosystem services and the interaction between final ecosystem services. The first relationship is discussed in Section 1.2.4.2. The second type of functional relationship considered is the interaction between final ecosystem services, which include positive or negative, unidirectional or bidirectional, and opposite or same direction (Bennett et al. 2009). I analyzed these relationships using the visual of a matrix with all ecosystem services across both axes. Within the cells of the matrix, I denoted the possible relationships between the respective ecosystem services.

The second step was to refer to descriptive language from the first focus group on how participants value, associate, and conceive of the ecological relationships underlying the provision of final ecosystem services. This information was used to further refine the degree of differentiation across survey items. The third step was to determine the structure of each survey item. I structured survey items with the minimum objective of deriving preference weights on a cardinal scale via the method of paired comparisons. The resulting survey items are not provided in this document. Instead, the final set of survey items are presented after Objective 4 in Table 2.

#### 2.4.4 Objective 4: Test survey items for stated-preference valuation requirements

This objective encompasses the fourth step of recomposition: refining survey item content, form, and structure with the objective of meeting the criteria listed in Section 2.1.2. Three second meetings of the coastal and non-coastal focus groups were held to complete this objective.

With the objective of minimizing potential sources of bias in stated-preference methods (discussed in Section 1.2.3.3), questions developed for the second meeting of the focus groups were as follows:

1. In order to measuring the understandability prima facie of the phrasing of the survey item, questions included:
   - Does this survey item make sense as it is worded now?
   - Is there another way to say this that is clearer?
   - Would you be able to respond to this, or is it confusing?

2. In order to identify features included in respondents' understanding of the survey item, which confirms that participants understand the survey item to refer to the same ecosystem services as scientists understand them to, questions included:
   - What comes to mind when you read this survey item?
   - What features of the environment are included in this survey item?
   - What would this survey item look like if it increased or decreased?

3. In order to generate measurements for monitoring change in each survey item over time, which inform the choice of bioindicators to include in the survey items and what form they should take, questions included:
   - How would you notice this survey item changing over time?

- Has this survey item changed in the past ten years?

4. In order to measure the level of detail necessary to present in each survey item, which informs the question of differentiability discussed above, questions included:
   - Are any of these survey items similar enough that they can be combined?
   - Is there too much information in this survey item?
   - Should it be split into two separate survey items?

*2.4.4.1 Existence value for whole system processes*

The expert opinion and a second focus group meeting were used to test the survey item representing whole system processes for the general survey item criteria listed in Section 1.3, as well as the additional criteria listed in Section 2.3.2.1 (discussed in Section 1.2.4.2). The first step was to refined data from the first focus group on measures and metrics that represent whole system processes according to academic literature. The first focus group identified a number of measures and metrics:

1. Resilience to disturbances
2. Diversity of species
3. Mature range of organism size
4. Is not stressed or disturbed
5. Does not need management
6. Resembles a preserved area
7. Minimal human impact
8. General health
9. Biomass, density
10. Habitat diversity
11. Strong cycling of energy and materials

These eleven metrics most closely resembled those used by ecologists to quantify measures of marine ecosystem health and integrity. In order to identify related bioindicators, therefore, I reviewed the literature on ecosystem health and integrity (Burkhard et al., 2011; Leo, 1997; Müller, 2000; Parrish et al., 2003), indexes of biotic integrity (Johnston et al., 2010; Karr, 1991), and indicators used to measure deviation from undisturbed areas and across disturbance gradients (Sousa et al., 2009). Results are presented in Table 3.

I presented resulting bioindicators during a second focus group meeting. Questions were aimed at gathering three types of data:

1. A measure of how representative bioindicators were of the concept of ecosystem whole system processes. The principal question was:
   - Do these indicators relate to your understanding of whole system processes?

2. A measure of the interpretability and appropriate wording of the bioindicators. Questions included:
   - Does this indicator make sense as it is worded now?
   - Is there another way to say this that is clearer?
   - Would you be able to respond to this, or is it confusing?

3. A measure of the welfare relevance of the bioindicator (i.e. 0 alone but >0 when representing whole system processes). Questions included:
   - Would an improvement to this bioindicator be worth anything if it did not contribute to any other changes in the ecosystem?

## 2.5 IMPLEMENTATION STUDY RESULTS

### 2.5.1 Benefits

A total of 13 specific ecologically derived benefits resulted from the first focus group meetings (presented below in Table 2). Benefits listed are streamlined versions of those benefits explicitly identified by participants in response to prompting. It should be noted that participants identified benefits in order to identify and compartmentalize related ecosystem services. Benefits are presented below with the same purpose, rather than as an endpoint of the analysis.

### 2.5.2 Final Ecosystem Services

I synthesized results of the first focus group meeting in order to generate a complete and parsimonious list of final ecosystem services. This process resulted in a total of 24 final ecosystem services (presented along with other metrics in Tables 2, 3, and 5).

### 2.5.3 Bioindicators

A total of 115 bioindicators resulted from the production function analysis (see Table 3). Note that this set of bioindicators are those that indicate the provision of final ecosystem services, and are therefore appropriate for biological monitoring but not necessarily appropriate for inclusion in a stated preference survey instrument. The latter are a subset that are designed and tested in further steps, and are presented in different language in Table 4.

### 2.5.4 Survey Items

The study resulted in 11 survey items, presented in Table 4. The content and structure of each survey item is designed to communicate a specific type of information in order to be applicable to a range of survey methodologies. Specifically, the survey items resulting from this study include a title, a description, and a set of associated bioindicators with titles and descriptions. This range of information provides a starting point for development of stated preference valuation surveys employing either *ordinal, cardinal* or *ratio* scales. For example, survey items can be treated as ordinal metrics in a ranking exercise. Survey items can also be treated as cardinal metrics in a trade-off exercise to derive relative preference weights for each survey item. The method of paired comparisons is a weight solicitation technique particularly amenable to this task because it is facilitates the weighting of multimetric entities with incommensurate values such as ecosystem services (Chan et al., 2012; Chuenpagdee et al., 2010; Hanley et al., 1998; Naidoo & Adamowicz, 2005). Lastly, survey items could be disaggregated and applied within an attribute-based contingent valuation survey (see Johnston et al., 2010).

**Table 2.** Final benefits and final ecosystem services

| | Benefits | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Final Ecosystem Services** | Physical activity and recreation | avoidance of pollution | Psychological and emotional health | Viewing of scenery | Viewing of wildlife | Using the beach | consumption of seafood | Catching fish and invertebrates | Food security and sustainability | Cultural identity | Ecological knowledge | Opportunity for stewardship and conservation |
| Production of harvested fish biomass | | | ■ | | ■ | | ■ | ■ | ■ | ■ | ■ | |
| Production of harvested invertebrate biomass | | | ■ | | ■ | | ■ | ■ | ■ | ■ | ■ | |
| Production of non-harvested fish biomass | | | ■ | | ■ | | | | | ■ | ■ | |
| Production of non-harvested invertebrate biomass | | | ■ | | ■ | | | | | ■ | ■ | |
| Production of marine mammal biomass | | | ■ | | ■ | | | | | ■ | ■ | |
| Production of sea bird biomass | | | ■ | | ■ | | | | | ■ | ■ | |
| Ecological maintenance of harvested invertebrate populations | | | ■ | | | | ■ | | ■ | | ■ | |
| Ecological maintenance of harvested fish populations | | | ■ | | | | ■ | | ■ | | ■ | |
| Production of genetic diversity across fish species | | | ■ | | ■ | | | | | ■ | ■ | |
| Production of genetic diversity across invertebrate species | | | ■ | | ■ | | | | | ■ | ■ | |
| Production of genetic diversity across marine mammal species | | | ■ | | ■ | | | | | ■ | ■ | |
| Production of genetic diversity across seabird species | | | ■ | | ■ | | | | | ■ | ■ | |
| Removal of biological waste in water | | ■ | | | | | | | | | ■ | |
| Removal of chemical contaminants from water | | ■ | | | | | | | | | ■ | |
| Deposition and retention of sand | ■ | | | ■ | | ■ | | | | ■ | ■ | |
| Formation of intertidal structure | ■ | | | ■ | | ■ | | | | ■ | ■ | |
| Production of kinetic wave energy | ■ | | | ■ | | | | | | ■ | | |
| Support of leisure and recreation | ■ | | | | | ■ | | ■ | | | | |
| Formation of socially-valued seascapes | | | | ■ | | | | | | | | |
| Production of visible macroalga biomass | | | ■ | ■ | | | | | | ■ | ■ | |
| Production of visible aquatic plant biomass | | | ■ | ■ | | | | | | ■ | ■ | |
| Ecological maintenance of whole system processes | | | ■ | | | | | | | | ■ | ■ |
| Support of social and cultural relations | | | | | | | | | | ■ | | ■ |
| Support of socially-valued lifestyle | | | | | | | | | | ■ | | |

**Table 3.** Final ecosystem services and bioindicators indicating their provision

| Final Ecosystem Services | Bioindicators |
|---|---|
| Production of harvested invertebrate biomass | Growth of harvested invertebrates<br>Average size (length) of harvested invertebrates<br>Abundance (count) of harvested invertebrates<br>Density (% cover, or #individuals/100 m2) of harvested invertebrates<br>Biomass accumulation among harvested invertebrate community assemblages<br>Growth of focal species[3]<br>Average size (length) of focal species<br>Abundance (count) of focal species<br>Density (% cover, or #individuals/100 m2) of focal species |
| Production of harvested fish[1] biomass | Growth of harvested fish<br>Average size (length) of harvested fish<br>Abundance (count) of harvested fish<br>Density (#individuals/100 m2) of harvested fish<br>Biomass accumulation among harvested fish community assemblages<br>Growth of adult focal species[2]<br>Average size (length) of adult focal species<br>Abundance (count) of adult focal species<br>Density (#individuals/100 m2) of adult focal species<br>Biomass accumulation among adult focal species community assemblages |
| Production of non-harvested fish biomass | Growth of non-harvested larger/conspicuous demersal fish<br>Growth of non-harvested forage fish<br>Average size (length) of non-harvested larger/conspicuous demersal fish<br>Average size (length) of non-harvested forage fish<br>Abundance (count) of non-harvested larger/conspicuous demersal fish<br>Abundance (count) of non-harvested forage fish<br>Density (#individuals/100$m^2$) of non-harvested larger/conspicuous demersal fish<br>Density (#individuals/100$m^2$) of non-harvested forage fish<br>Biomass accumulation among sedentary focal species community assemblages |
| Production of non-harvested invertebrate biomass | Growth of non-harvested large macroinvertebrates (solitary and colonial)<br>Average size (length) of non-harvested large macroinvertebrates (solitary and colonial)<br>Abundance (count) of non-harvested large macroinvertebrates (solitary and colonial)<br>Density (% cover, or #individuals/100 m2) of non-harvested large macroinvertebrates (solitary and colonial)<br>Biomass accumulation among non-harvested large macroinvertebrate community assemblages |

**Table 3. (Continued)** Final ecosystem services and bioindicators indicating their provision

| Final Ecosystem Services | Bioindicators |
|---|---|
| Production of marine mammal biomass | Haul out total density counts[4]<br>Pup counts[4]<br>Abundance (count) of seals and sea lions<br>Abundance (count) of whales[5]<br>Average size of marine mammals |
| Production of sea bird biomass | Nesting colony total density (count)[6]<br>Growth of seabirds<br>Average size of seabirds<br>Abundance (count) of seabirds<br>Density (% cover, or #individuals/100 m2) of seabirds<br>Biomass accumulation among community assemblages |
| Ecological maintenance of harvested invertebrate populations | Age distribution of harvested invertebrate species[b]<br>Mean age of focal species[b]<br>Lifetime egg production[c]<br>Larval connectivity[c,7]<br>Individual replacement[c]<br>Urchin aggregation densities[8] |
| Ecological maintenance of harvested fish populations | Age distribution of harvested fish species[b]<br>Mean age of focal species[b]<br>Lifetime egg production[c]<br>Larval connectivity[c,7]<br>Individual replacement[c] |
| Production of genetic diversity across fish species | Fish community diversity indices[9] |
| Production of genetic diversity across invertebrate species | Invertebrate community diversity indices[9] |
| Production of genetic diversity across marine mammal species | Marine mammal community diversity indices[9] |
| Production of genetic diversity across seabird species | Seabird species diversity indices[9] |
| Removal of biological waste in water | Density of denitrifying organisms<br>Density of microalgae<br>Microbenthophytic assimilation<br>Abundance of suspension feeding organisms<br>Average size of suspension feeding organisms |

**Table 3. (Continued)** Final ecosystem services and bioindicators indicating their provision

| **Final Ecosystem Services** | **Bioindicators** |
|---|---|
| Ecological maintenance of whole system processes | 1. Resilience to disturbances (resilience)<br>Food web integrity<br>Colonization and local extinction rates<br>Local recruitment rate<br>Recruitment success<br>Survivorship<br>2. Diversity of species (biodiversity)<br>Species evenness<br>Genetic diversity<br>3. Mature range of organism size (population structure)<br>Age ratio<br>Sex ratio<br>Spawning biomass<br>Trophic role<br>Growth rates of individuals<br>Life-form proportions<br>Biomass ratios (e.g. pelagic vs. demersal)<br>Breeder biomass<br>4. Is not stressed or disturbed (functioning)<br>Functional diversity<br>5. Does not need management (self-organization)<br>Ascendancy<br>Development capacity<br>Emergence<br>6. Representative of natural comparison (representativeness)<br>Species distribution patterns<br>Relative species abundance<br>7. Human impact (naturalness)<br>Area under no or reduced direct human impact<br>Area showing signs of recovery<br>8. Parasitism (health)<br>Parasitism rates<br>9. Biomass, density (productivity)<br>Total benthic production<br>Total biomass (community) |

**Table 3. (Continued)** Final ecosystem services and bioindicators indicating their provision

| Final Ecosystem Services | Bioindicators |
|---|---|
| Ecological maintenance of whole system processes (continued) | 10.Habitat (structure)<br>Biotic habitat heterogeneity<br>Abiotic habitat heterogeneity<br>Habitat complexity<br>Habitat integrity<br>11.Nutrient and energy flow (thermodynamics)<br>Net primary production<br>Storage capacity<br>Nutrient cycling<br>Nutrient loss<br>Nutrient cycling rates<br>Size distribution<br>Average trophic level |
| Removal of chemical contaminants from water | Density of denitrifying organisms<br>Density of microalgae<br>Microbenthophytic assimilation<br>Abundance of suspension feeding organisms<br>Average size of suspension feeding organisms |
| Deposition and retention of sand | Sedimentation<br>Magnitude and variation of depositional currents |
| Formation of intertidal structure | Geologic formation<br>Density of habitat-forming invertebrate species[10] |
| Formation of socially-valued seascapes | n/a |
| Production of visible macroalga biomass | Percent cover (density) of surface canopy-forming kelp species[11]<br>Area of surface canopy-forming kelp species |
| Production of visible aquatic plant biomass | Percent cover (density) of intertidal and subtidal seagrass species<br>Area of intertidal and subtidal seagrass species[14] |
| Production of kinetic wave energy | Formation of nearshore relief<br>Loss of buffering geologic structure<br>Loss of buffering biogenic structure<br>Loss of nearshore macroalgae |
| Support of social and cultural relations | n/a |
| Support of leisure and recreation | n/a |
| Support of socially-valued lifestyle | n/a |

**Table 3. (Continued)** Final ecosystem services and bioindicators indicating their provision

Sources:
[b] (Oregon Department of Fish and Wildlife, 2012)
[c] (Botsford et al., 2008)
[1] Includes adult groundfish (43 species), cartelagenous fish, flatfish, forage fish (e.g., sand lance, smelts, anchovies, herring, and sardines), and larger conspicuous demersal fish (Oregon Department of Fish and Wildlife, 2012)
[2] "Focal species" refers to fish that are commonly harvested, economically important, and exhibit small home ranges. Species regularly found within each reserve may include: kelp greenling, lingcod, Cabazon, black, blue, China and quillback rockfish (Oregon Department of Fish and Wildlife, 2012)
[3] "Focal species" refers to economically important species, such as Dungeness crab and red urchin, or solitary (i.e. not colonial) and relatively abundant (e.g., habitat forming species such as *Metridium* anemones, *Gorgonocephalus* basket stars) (Oregon Department of Fish and Wildlife, 2012)
[4] Includes harbor seals, California sea lions, and Stellar sea lions (Oregon Department of Fish and Wildlife, 2012)
[5] Primarily gray whales (Oregon Department of Fish and Wildlife, 2012)
[6] Most of the larger offshore rocks and many cliffs along the shore have seabird nesting colonies (Oregon Department of Fish and Wildlife, 2012)
[7] Specific connectivity patterns depend on relevant population structures (Botsford et al., 2008)
[8]Aggregation density correlates with larval output and probability of fertilization, a concept called the Allee effect (Oregon Department of Fish and Wildlife, 2012)
[9]Diversity indices include species richness, Shannon-Wiener, Simpson's and Berger-Parker biodiversity indices, as well as the species value index and density for each species (Oregon Department of Fish and Wildlife, 2012)
[10]e.g., Metridium anemones, Gorgonocephalus basket stars (Oregon Department of Fish and Wildlife, 2012)
[11] e.g., Nereocystis and Macrocystis (Oregon Department of Fish and Wildlife, 2012)

**Table 4.** List of 24 final survey items

| Survey item title | Survey item description | Bioindicator title | Bioindicator description |
|---|---|---|---|
| The variety of sealife | This item represents the diversification of fish, shellfish, marine mammal, and plant and algae species *inside* protected areas. An increase in this item would mean new species of plants and animals could be seen or uncommon plants or animals might become more common. A decrease would mean the range of species seen would go down and some animals might become more rare. | "Number of species" | The total number of species observed |
| | | "Relative abundance" | How common or rare a species is relative to other species |
| The abundance of seabirds | This item represents the natural production of seabirds *inside* protected areas. An increase in this item would mean more seabirds (e.g. pigeon guillemot) could be seen in flight or on the rocks or water in the marine reserves. A decrease would mean these animals would be less commonly seen. | "Seabird abundance" | The number of seabirds observed |
| | | "Nesting population" | The size of seabird nesting colonies |
| The abundance of marine mammals | This item represents the natural production of marine mammals *inside* protected areas. An increase in this item would mean more marine mammals (e.g. Pacific harbor seals, California sea lions, grey whales) can be seen in the water or on rocks from the shore or while in the water. A decrease would mean these animals would be less commonly seen. | "Seal abundance" | The number of Pacific harbor and Northern elephant seals observed |
| | | "Sea lion abundance" | The number of California and Stellar sea lions observed |
| | | "Whale abundance" | The number of grey and other whale species observed |
| The natural integrity of the marine ecosystem | This aspect represents the ability of the marine ecosystem (*inside and outside* of protected areas) to self-organize and support a mature, rich community of organisms. An increase in this aspect means organism populations and interactions (such as the food web) naturally become more functional and resilient. A decrease would mean more reliance on and signs of human intervention and management. | "Recruitment success" | The amount of larval input, settlement, and survival (from new births or new entrants) |
| | | "Average trophic level" | The distribution of organisms throughout the food chain |
| | | "Biodiversity index" | The relative abundance of each species |
| | | "Size distribution" | The range of sizes of individuals within each species |
| | | "Primary production" | The growth in number and size of photosynthesizing organisms (aquatic plants, algae, phytoplankton) |
| | | "Habitat complexity" | The degree of variation in habitat types |
| | | "Direct human impacts" | Visually apparent signs of human use (past or present) |

**Table 4. (continued)** List of 24 final survey items

| Survey item title | Survey item description | Bioindicator title | Bioindicator description |
|---|---|---|---|
| The cleanliness of coastal waters | This item represents the coastal water quality (*within and outside* protected areas) with respect to human contact and consumption of local seafood. An increase in this item means an improvement to the natural processes and organisms that remove biological and chemical waste from coastal waters. A decrease means less removal of waste and poorer water quality. | "Water quality" | The level of nutrient concentrations, suspended solids, and industrial contamination |
| | | "Nutrient recycling" | The rate at which nutrients are recycled into living matter |
| | | "Filter feeder biomass" | The number and size of organisms that filter the water (e.g. mussels and clams) |
| The coastal culture and lifestyle | This item represents the vitality of the culture and lifestyle that Oregonians consider characteristic of the coast. An increase in this item means that coastal communities exhibit a stronger economic, social, and cultural connection to the ocean. A decrease means that these aspects of the communities are less tied to the ocean and ocean-based activities. | "Ocean-based tourism" | Employment, income, and investment from ocean-based tourism (e.g., whale watching, sea kayaking, etc.) companies |
| | | "Research and education" | Employment, income, and investment from marine research institutions, aquariums, and other educational ventures |
| | | "Stewardship opportunity" | The amount of personal and professional activity dedicated to natural resource supervision (e.g. beach clean ups, conservation organizations) |
| | | "Fishing and seafood" | Employment, income, and investment from the commercial and recreational fishing sectors, seafood processing sectors, and seafood preparation industry |
| The number and size of fish and shellfish | This item represents the natural production of all fish and shellfish (harvested and non-harvested) *within* protected areas. An increase in this item would mean that there would be more and larger fish, crabs, sea stars, and anemones present while diving, for example. A decrease would mean that there would be less of these visible species, and they would be smaller on average. | "Growth rate" | How quickly large fish and shellfish grow in size and weight |
| | | "Abundance" | The number of large fish and shellfish present within the reserve |
| | | "Focal species biomass" | The number and size of all sedentary rockfish and red urchins in the reserve |
| The natural aesthetic of the seascape | This item represents the natural formation of pleasant coastal scenery *inside* protected areas. An increase in this item means more areas displaying the natural features and dynamics that Oregonians find inspiring. A decrease means these areas would display less of these features and the dynamics would be modified. | "Wave patterns" | The degree to which the flow of water and waves is unimpeded by structures |
| | | "Colonized rock" | The proportion of above-water rocky formations that are colonized by plants and animals |
| | | "Visible kelp, plants and algae" | The amount of surface canopy forming kelp and intertidal plants and algae |

**Table 4. (continued)** List of 24 final survey items

| Survey item title | Survey item description | Bioindicator title | Bioindicator description |
|---|---|---|---|
| Areas for outdoor recreation and leisure | This item represents the amount of areas suitable and available for outdoor recreation and leisure *inside or adjacent to* protected areas. An increase in this item means more natural supply of accessible beach, tide pools, swimmable areas, etc. A decrease means these areas would diminish in quantity and quality. | "Beach area" | The amount of beach sand naturally deposited and retained |
| | | "Tide pool abundance" | The number of organisms (e.g. snails, sea stars) in tide pools and intertidal areas |
| | | "Water supporting (non-fishing) recreation" | The amount of coastal waters used for diving, surfing, swimming, kayaking, etc. (but not fishing) |
| The availability of fish and shellfish for harvest | This item represents the natural production of all harvestable fish and shellfish outside the marine reserves. An increase in this item would mean an increase in the stock size of legal-size fish and shellfish of those species available for commercial and recreational harvest. A decrease would mean a lower stock size and fewer legal size fish. | "Relative abundance" | The proportion of stocks of harvested species to non-harvested species |
| | | "Average size" | The average length and weight of harvested species |
| | | "Focal species biomass" | The number and stock size of economically important species (e.g., Dungeness crab, black rockfish) |
| | | "Catchable spillover" | The degree to which legal-size adults cross reserve boundaries into fished areas |
| | | "Reproductive spillover" | The degree to which fish within the reserve contribute eggs and larvae to fished areas |
| The natural sustainability of the local fish and shellfish stock | This item represents the natural ability of the harvested fish and shellfish populations outside protected areas to persist into the long-term future. An increase in this item would mean that stocks are more resilient to fishing or natural disturbance, and are more able to reproductively replace individuals. A more sustainable stock also allows for a larger stock size. A decrease would mean that stocks would have difficulty repopulating and therefore might be more vulnerable to overfishing or environmental changes in the future. | "Harvest limit" | The amount of fish and shellfish allowed for harvest each year |
| | | "Age distribution" | The age demographics of economically important species |
| | | "Biomass buildup" | The growth and accumulation of harvested species within the marine reserve |
| | | "Lifetime egg production" | The number of eggs produced by an individual over the course of its lifetime |

**Table 5.** Inclusion of 24 final ecosystem services in 11 final survey items

| **Final Ecosystem Services** / **Survey Items** | The availability of fish and shellfish for harvest | The number and size of fish and shellfish | The abundance of marine mammals | The abundance of seabirds | The natural sustainability of the local fish and shellfish stock | The variety of sealife | The cleanliness of coastal waters | Areas for outdoor recreation and leisure | The natural aesthetic of the seascape | The natural integrity of the marine ecosystem | The coastal culture and lifestyle |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production of harvested fish[1] biomass | ■ | | | | | | | | | | |
| Production of harvested invertebrate biomass | ■ | | | | | | | | ■ | | |
| Production of non-harvested fish biomass | | ■ | | | | | | | | | |
| Production of non-harvested invertebrate biomass | | ■ | | | | | | | ■ | | |
| Production of marine mammal biomass | | | ■ | | | | | | | | |
| Production of sea bird biomass | | | | ■ | | | | | | | |
| Ecological maintenance of harvested invertebrate | | | | | ■ | | | | | | |
| Ecological maintenance of harvested fish populations | | | | | ■ | | | | | | |
| Production of genetic diversity across fish species | | | | | | ■ | | | | | |
| Production of genetic diversity across invertebrate species | | | | | | ■ | | | | | |
| Production of genetic diversity across marine mammal | | | | | | ■ | | | | | |
| Production of genetic diversity across seabird species | | | | | | ■ | | | | | |
| Removal of biological waste in water | | | | | | | ■ | | | | |
| Removal of chemical contaminants from water | | | | | | | ■ | | | | |
| Deposition and retention of sand | | | | | | | | ■ | | | |
| Formation of intertidal structure | | | | | | | | ■ | ■ | | |
| Production of kinetic wave energy | | | | | | | | ■ | | | |
| Support of leisure and recreation | | | | | | | | ■ | | | |
| Formation of socially-valued seascapes | | | | | | | | | ■ | | |
| Production of visible macroalga biomass | | | | | | | | | ■ | | |
| Production of visible aquatic plant biomass | | | | | | | | | ■ | | |
| Ecological maintenance of ecosystem health and integrity | | | | | | | | | | ■ | |
| Support of social and cultural relations | | | | | | | | | | | ■ |
| Support of socially-valued lifestyle | | | | | | | | | | | ■ |

## 2.6 DISCUSSION

### 2.6.1 Benefits

Like all data generated by this study, the benefits identified are very specific to the study group. Furthermore, the identification of benefits is not intended to be an analytical endpoint, but rather an analytical starting point with two main functions. The first function is to allow focus group participants to identify final ecosystem services, and by extension allow me to identify SPUs/ESPs and bioindicators. The second function is to illustrate how focus group participants conceptualize and utilize the marine environment, which in turn informs the initial phrasing of survey items and provides guidelines for monitoring efforts. With respect to monitoring, quantifying the contribution of final ecosystem services to changes in benefits should be a priority of researchers.

### 2.6.2 Final Ecosystem Services

The final ecosystem services identified in this study reflect how the study participants conceptualized the natural delivery of ecosystem-derived benefits, and therefore are most illustrative of the perspectives of these particular groups of people. Nevertheless, each repetition of the focus groups gleaned a diminishing number of new ecosystem services. This pattern suggests that repeating the exercise on a regional scale might result in a similar list. The implications of this pattern are discussed in more detail in Chapter 4.

Another interesting pattern that emerged was the way in which participants identified provisioning, regulating, supporting, and cultural services (Millenium Ecosystem Assessment, 2006) varied. This variation may be more indicative of the limits of the approach than the specific study population, and can therefore inform future application of the approach. For example, what would be considered provisioning services were most readily and clearly identified by participants of the first focus group meetings. Provisioning services include those that begin with “Production of” and “Formation of,” (with the exception of *Formation of socially-valued seascapes*) as well as *Deposition and retention of sand*. These two terms are both intended to communicate an increase in quantity but in different ways—the former being more instantaneous and the latter being more accumulative. One explanation for these services being most readily identified that provisioning services generally describe the delivery of an ecosystem good. Ecosystem goods are by definition utilized directly (Boyd & Banzhaf, 2007; Fisher et al., 2008; Fisher & Turner, 2009; Johnston & Russell, 2011; Wallace, 2008), a quality that closely matches the operational definition of an ecosystem services. 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 non-harvested fish biomass* and *Provision of harvested fish biomass* 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 able to view both targeted and non-targeted species.

What would be considered cultural services were the next most easily and readily identified. Cultural services include *Support of leisure and recreation, Support of social and cultural relations*, *Formation of socially-valued seascapes,* and *Support of a socially-valued lifestyle*. Participants readily identified these services in part because of the value they place on their culture and social fabric, and also because of the multi-dimensional nature of these services. Participants displayed a strong yet irreducible identity with the culture of the Oregon coast, and their descriptions of this feeling were often nebulous, romanticized, and not directly attributable to any natural features or qualities over others. As a result, participants at times resisted the task of extricating discrete ecosystem services and gravitated towards describing social and psychological benefits. I addressed these challenges by devising these ecologically indistinct services. As a result, they are not linked to bioindicators (see “n/a” in Table 3).

Since these four services do not describe discrete biophysical features and qualities, they cannot be unambiguously linked to bioindicators but rather must be linked to socioeconomic indicators. 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, three of these services contribute to a survey item that only includes socioeconomic metrics (*The coastal culture and lifestyle*). Stakeholders also noted that the socially-valued natural aesthetic of the seascape is provisioned by the interaction of all natural features. This less discrete element is represented in the ecosystem service, *Provision of a socially-valued seascape,* which combines with *Production of visible macroalga biomass* and *Production of visible aquatic plant biomass* in the survey item *The natural aesthetic of the* *seascape*. As Table 5 demonstrates, potential for double-counting exists with this survey item to the degree that the inclusive services are not distinguished from each other.

Focus group participants also identified what would be considered regulating services less readily than provisioning services. Regulating services include those beginning with "Ecological maintenance of" and "Removal of." Regulating services are distinct from provisioning services in that, in addition to the quantity of an environmental feature, they imply criteria for the delivery of the service. For example, the service *Ecological maintenance of harvested fish populations* implies a dynamic in the supply of rather than the provision of the fish at any given moment. The fact that these services were not identified as readily as provisioning or cultural services was not a result of a limitation to this approach. Rather, it highlights that the focus group discussion becomes more in depth as it moves on, and only later in the discussion are criteria—and therefore services implying criteria—identified.

Lastly, services that would be by definition supporting services were not identified as such in this study because they are not directly utilized are therefore unfit for stated-preference valuation (Rudd, 2007). However, services that are traditionally considered supporting services (e.g. *Ecological maintenance of whole system processes*) did provide direct benefits to participants and were therefore articulated in this study. See Section 2.6.3.1 below for a more detailed discussion of the implications such services have on future applications of the approach.

### 2.6.3 Survey items

The two main challenges to finding the appropriate phrasing of survey items are determining what information to include and determining the degree to which that information is differentiated. Researchers applying the approach should not make such determinations formulaically, but rather should respond to the needs of participants. Nonetheless, the implementation study provided examples that could serve as "lessons learned" to future applications of the approach.

Determining what information to include in survey items is a balancing act aimed at making the survey items meaningful to respondents. 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." A prime example of my effort to find the optimal amount of such language was with the phrasing of the survey item *The resilience of the local fish and shellfish stock.* This survey item was originally phrased to include descriptive language gathered from the first meeting concerning the importance of the economic multiplier effect that seafood has in the local economy as: *The resilience of the fish and shellfish stock to catch, eat, and market locally*. However, participants of both focus groups had trouble interpreting it due to ambiguous and encumbered language, and thought the phrase elicited thoughts of the economic market for fish, rather than those species that are available for recreational and commercial harvest. For this reason, I jettisoned "to catch, eat, and market locally" in favor of a simpler and biologically-focused survey item to which participants could ascribe their own meaning.

Determining the degree to which survey items differentiate the commodities presented was another challenge. In general, I favored differentiation where possible for four reasons. First, differentiation provides concise, singular commodities that respondents found as easy to respond to. 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) (Kontogianni et al., 2010). 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. I 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.

For example, I present *The abundance of seabirds* as differentiated from *The abundance of marine mammals*, while I presented *The variety of sealife* as an undifferentiated commodity. The first two were originally presented as an undifferentiated commodity (i.e. *The abundance of mammals and seabirds*), but participants commented that it should be divided into two survey items because some individuals participate in bird watching or whale watching and not the other. Conversely, *The variety of sealife* is undifferentiated (i.e. not *The variety of fish*, *The variety of marine mammals*, 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 a survey item nor the presentation of a survey item avoid expansive priors in general, but this survey item 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).

Lastly, the analysis of the ecological interactions between final ecosystem services and their provision did not ultimately change, but rather confirmed, the degree of differentiation of survey items that resulted from focus group input. This result is suggests that focus group participants understand the basic ecology behind the provision of final ecosystem services. Such an understanding facilitates the ability of related survey items to meet the theoretical requirements described in Section 1.3.

#### *2.6.3.1 Whole system processes*

Development of the survey item representing existence value for whole system processes resulted in *The natural integrity of the marine ecosystem*. The term “natural integrity” was chosen by the focus group participants as best describing their concept of whole system processes. It should be noted that this term implies complex values on the part of participants, a topic that is discussed in more detail in the following chapter. This survey item also involved additional consideration and a different methodology from other items. In short, the criteria for bioindicators included in this survey item were that they elicit WTP of 0 alone, but WTP of >0 when indexed to represent whole system processes, or represent systemic qualities that elicit WTP if changes to all other benefits are held constant. The proceedings of the focus groups suggested that the methodology was constructive, as it allowed participants to better articulate their conceptualization of a concept that was very important to them but they found occult. When presented with the scientific language of the bioindicators, however, they immediately identified the attendant concepts as making inherent sense. This result should encourage the inclusion of technical bioindicators in survey instruments.

#### *2.6.3.2 Cultural ecosystem services*

The survey item *The coastal culture and lifestyle* by design does not include bioindicators and therefore does not conform to the approach. Still, I included this survey item in order to provide a means to 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. Furthermore, while change in this survey item cannot be directly related 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 survey item), its measurement provides a means for modeling such correlations as part of monitoring efforts.

### 2.6.4 Bioindicators

This study resulted in two sets of bioindicators. The first is the full set (Table 3); the second is the subset included in survey items (Table 4). While these two sets are specific to this study and the specific marine environment within which it was conducted, generation of these two lists in future applications of the approach can be beneficial. First, generating a full list expands the capacity for biological monitoring. For example, identifying correlations between the full set and the subset included in survey items could identify potential for indexing through a scaling function. Efficiencies in measurement could also be facilitated by focusing on community-level bioindicators that may correlate with population or species level bioindicators.

## 2.7 CONCLUSION

This section presents concluding thoughts on the applicability of the approach, the methods used in the implementation study, the limitations of the approach, potential policy applications of the approach and its outputs, and a discussion of future extensions of the approach and the implementation study survey items.

The overarching purpose of this chapter was to develop and test an approach for evaluating tradeoffs associated with marine spatial planning in Oregon. This approach was designed with specific criteria to meet certain objectives, which in turn determined the final product and its potential applications. The analysis conducted in this chapter can therefore be analyzed on three levels. The first level pertains to policy contexts within which the approach was designed: the practice of MSP in Oregon and the principles and practices of EBM in the United States. These policies provide the criteria for the approach's design, the general objectives of the approach, and the criteria for meeting those objectives. The second level pertains to the analytic objective of the approach: to generate survey items of marine ecosystem services that can be used to evaluate the ecological and socioeconomic tradeoffs associated with marine spatial planning in Oregon. This level includes the theoretical requirements of those survey items and attendant methodological objectives. The third level is the application of these survey items within a tradeoff analysis to inform nearshore management decisions in Oregon. This application is discussed in Chapter 3. The practical and theoretical considerations on the first two levels, as well as the methods of achieving them, are discussed in turn below.

### 2.7.1 Approach Design

The approach is designed to provide a tool to inform a specific application of MSP in accordance with EBM. In particular, its focus is to meet objectives of EBM: the conservation of provision of ecosystem services (McLeod & Lubchenco, 2005), and the consideration of common social values and preferences within a scientific understanding of the ecosystem (Crowder & Norse, 2008). The approach met the first objective through the measurement and valuation of marine ecosystem services. Other applications include systematizing or organizing ecosystem services, quantifying ecosystem services, and mainstreaming of ecosystem services into social behavior or policy and management decisions (Nahlik et al., 2012). The approach met the second objective through engaging the stakeholder community in order to integrate ecological and economic analysis. A more detailed discussion of these topics is presented in Chapter 4.

### 2.7.2 Approach Objectives

The second level on which the study can be analyzed pertains to the analytic objective of the approach: to generate survey items of marine ecosystem services that can be used to evaluate the ecological and socioeconomic tradeoffs associated with marine spatial planning in Oregon. In order to achieve this objective, survey items were required to meet certain theoretical requirements (listed in Section 2.1.3). In order to derive survey items that meet these requirements, the study had four methodological objectives: 1) Identify final ecosystem services valued by coastal resource stakeholders in Oregon; 2) Define structural linkages between final ecosystem services and bioindicators of their provision; 3) Develop survey items of final ecosystem services appropriate for stated-preference valuation, and; 4) Test survey items for their ability to meet stated criteria. This section discusses the general survey item objectives at each of these four points in the approach methodology.

#### *2.7.2.1 Identifying ecosystem services*

I identified final ecosystem services valued by coastal resource stakeholders in Oregon through direct questioning during focus group meetings. This approach is described in Section 2.3.2. Reliance on stakeholder engagement to identify and characterize ecosystem services stems from the ecosystem service definition and classification system used (see Section 2.2.1), which requires that ecosystem services be defined by "backing out" from associated benefits as described by ecosystem service beneficiaries. The approach was operationalized successfully, although many lessons were learned about how to effectively engage stakeholders for this purpose.

#### *2.7.2.2 Identifying bioindicators*

The requirement of this study that survey items link attributes of ecological models and ecosystem services that provide utility to respondents was achieved through identifying bioindicators of ecosystem service provision and integrating those bioindicators into the final survey items. Bioindicators were indentified by characterizing the provision of ecosystem services via SPUs/ESPs and their functional efficiency measures (see Section 2.3.4).

#### *2.7.2.3 Developing survey items*

Within stated-preference or survey-based valuation, the validity of welfare estimates depends on appropriately integrating ecological and economic information. The requirement of this study that survey items of final ecosystem services be appropriate for stated-preference valuation was therefore achieved through considerations of the relevant ecology, as well as considerations of stated-preference methodology. Ecological considerations included an analysis of the productive relationships between final ecosystem services and the identification of bioindicators of those services' provision (see Section 2.3.4). Economic considerations related to stated-preference methods include 1) the very practice of including bioindicators in survey items, 2) measures to ensure survey items are unambiguous and quantitatively commensurate with neoclassical utility models used for valuation, and 3) measures to ensure they provide information that is meaningful, comprehensive, and comprehensible to non-scientist survey respondents.

In order to for survey items to be commensurate with economic utility models, survey items are structured to solicit relative preference weights through a trade-off exercise. Stated preference surveys derive respondents' weights by scaling answers according to a metric of preference (Brown, 2003). The approach generates survey items appropriate for a method of paired comparisons, which generates weights on a cardinal scale. See Section 1.2.5.2 for a discussion of why a cardinal scale is most appropriate for this approach. In order for survey items to provide information that is meaningful, comprehensive, and comprehensible to respondents, survey items were initially structured and phrased with regard to a number of considerations. First, qualitative language from the first focus group meetings revealing participants' understanding of ecological relationships and their utility functions, including the connection between benefits and services, were included in survey items to ensure their meaningfulness. As discussed in Section 2.3.4, these considerations primarily influenced the degree of differentiation used to present survey items. Second, the full set of final ecosystem services identified in the focus group meetings was included in survey items to ensure they are comprehensive. It is important to note, however, that this set may not be comprehensive for a larger study population. Third, initial phrasing of survey items included not just a statement of inclusive ecosystem services and bioindicators but also statements of what those metrics mean to ensure they are comprehensible.

#### *2.7.2.4 Testing survey items*

Survey items were tested through a second focus group meeting in which participants were asked to react to the design of each survey item with respect to the above criteria. See Section 2.3.5 for a discussion of this methodology, as well as a list of questions asked participants.

### 2.7.3 Methods

As discussed in Section 2.3, a range of methods can be employed to operationalize the approach developed in this study. My choice of methods was guided by the specific research needs of the State of Oregon. Like all methods, the methods used in the implementation study had tradeoffs. Perhaps the most prevailing tradeoff was between the effort to adhere to certain principles of EBM and the complexity of certain tasks. For example, in the interest of adhering to principles of EBM, the method of stakeholder focus groups was used to identify final ecosystem services and test survey items for their ability to meet stated criteria. While focus groups certainly succeeded in engaging stakeholders in the MSP process, group dynamics and the challenge of moderating large focus groups complicated the task at hand. Alternatively, other methods of group-based identification and characterization of ecosystem services (Wilson & Howarth, 2002) could provide a more straightforward application of the approach.

The use of the ESP/SPU approach to define structural linkages between final ecosystem services and bioindicators of their provision is rudimentary but appropriate for the objectives of this study. Primarily, this approach to an ecological production function is not only sufficient (i.e. identified bioindicators), but in fact strengthens stated-preference methods (Kontogianni et al., 2010). Also, as discussed in Section 1.2.3.2, characterizing ecological production functions is a nascent area of research. Furthermore, studies that do attempt to characterize more complex ecological production functions note issues with uncertainty and nonlinear effects (Barbier et al., 2008; Sanchirico & Mumby, 2009).

The method of using expert opinion of researchers to develop survey items of final ecosystem services appropriate for stated-preference valuation was effective in this study. One could suggest, however, that pursuant to the principles and practices of EBM, stakeholder participation also be used to complete this step. While a focus group or deliberative discourse method would complicate the process of survey item development, it could be argued that the final set of survey items would more closely align with the utility functions of stakeholders. Also pursuant to the principles and practices of EBM, it is important that this step be grounded in a scientific understanding of the ecological linkages between survey items and inclusive ecosystem services. Therefore, if a stakeholder-based method of developing survey items were to be applied, it would have to be merged with the input of natural scientists.

### 2.7.4 Limitations

While the approach developed in this study is designed to be generically applicable to any marine spatial planning action, it is also designed to be adaptive to the specific context of its application in order to yield tailored outcomes. Consideration of this analysis should therefore account foremost for the unique population of stakeholders sampled to participate in this study. The list of final survey items generated by the approach is also only representative of the sampled population, and is neither generalizable to other populations nor necessarily exhaustive.

### 2.7.5 Policy applications

The third recommended characteristic of an ecosystem service assessment approach is that it be policy-relevant, and information gained through the approach should improve policy management decisions. The approach was originally designed to meet the specific needs of marine resource management agencies in Oregon, and as a result, the outputs—survey items and associated bioindicators for monitoring—are relevant to the state's nearshore management decisions. Even prior to application in a tradeoff analysis, the information generated in this chapter provides a guide for socioeconomic and biological monitoring efforts. In particular, the linkages between survey items and bioindicators allows for MSP actions with potential impacts on marine ecosystem services to translated into bioindicators used for monitoring and assessment—either prior to or after the implementation of regulations. The approach can be scaled up from the relatively small study communities and applied iteratively over time, and therefore is adaptable to policy scenarios of varying temporal and spatial scale.

As mentioned in Section 1.2.2, the process of operationalizing an ecosystem service approach using this classification system has not been explicitly conducted many times (Johnston & Russell, 2011; Johnston et al., 2010; Ringold et al., 2009). The lessons learned through this study therefore will contribute to a nascent effort by the scientific community to standardize transdisciplinary final ecosystem service stated preference valuation studies (Nahlik et al., 2012).

### 2.7.6 Future extensions

Baseline data is currently being collected at three other sites in Oregon where MPAs are scheduled to be established. The approach could be applied to these sites in order to expand or refine the set of survey items generated in this chapter. However, as is discussed in more detail in Chapter 4, managers and researchers should prioritize a larger, randomized administration of the survey developed in Chapter 3 over another full application of the approach. The reason for this is it is likely that implementing the approach from scratch with other communities will result in a similar list of benefits, final ecosystem services. Nevertheless, with the goal of administering the survey more broadly, a second research priority should be the refinement of survey items via methods used in this approach (i.e., Objective 4). The reason for this is while different focus groups identified similar benefits and ecosystem services, their interpretation of the language and presentation of the survey items was quite varied. This variation is likely to only expand with a larger, randomized sample population. In this step, managers and researchers might also consider incorporating other *pretest* protocols into refinement of the survey items.

In addition to expanding the sampled population, the survey items generated by the approach can also be expanded. Specifically, the survey items generated in this chapter provide a foundation for development of an attribute-based method similar to that developed by Johnston et al. (2011). Such an effort would allow for bioindicator-specific demand to be derived. For example, if a range of MPA alternatives were all thought to increase the overall provision of the ecosystem services included in the survey item *The number and size of fish and shellfish* but each alternative was expected to have a different effect on the bioindicators within that survey item, each bioindicator could be extracted and applied in a tradeoff exercise to derive specific demand curves.

# CHAPTER 3

# OREGON STAKEHOLDER VALUES FOR MARINE ECOSYSTEM SERVICES: AN IMPLEMENTATION STUDY

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## 3.1. INTRODUCTION

In an effort to meet the research needs of the State of Oregon and address the principles and practices of ecosystem-based marine spatial planning, the approach developed in this study is designed to meet the objective of measuring and valuing marine ecosystem services. As discussed in Section 2.1.2, this objective must be met according to three criteria (Nahlik et al., 2012): quantification and communication of the contribution of ecosystem services to human well-being; the evaluation of trade-offs between ecosystem services and between ecosystem services and "services generated through human efforts" (p. 28); and inclusion of the value of ecosystem services in the relevant resource management decision making process.

Chapter 1 detailed the policy context and theoretical foundations of the approach developed and tested in this study. Chapter 2 applied information from Chapter 1 to the development of the approach and documented an implementation study of the approach with communities in Oregon. The implementation of the approach resulted in a set of 11 survey items of marine ecosystem services that can be used to evaluate the ecological and socioeconomic tradeoffs associated with marine spatial planning (MSP) in Oregon. This chapter documents the design, development, and results of a survey instrument that employs these 11 survey items in order to meet the above objectives and criteria.

### 3.1.1 Implementation study goal and objectives

The goal of the implementation study presented in this chapter is to test the ability of the approach to inform nearshore management decision-making in Oregon by measuring and valuing marine ecosystem services. Survey items generated by the implementation of the approach are structured to allow marine ecosystem services to be valued in a tradeoff exercise. In order to quantify tradeoffs between ecosystem services, weights must be specified (Yoe, 2002). Survey items are therefore designed in order to generate relative preference weights via the method of paired comparisons. See Section 1.2.5.2 for a discussion of this method.

The analysis presented in this chapter has a number of analytic objectives related to how relative preference weights for survey items can inform nearshore management decisions in Oregon, including the creation, management, and monitoring of MPAs. The first analytic objective is to test if relative preference weights can be aggregated to aid decision-support through incorporation into decision matrices used in marine spatial planning. This objective is addressed in Section 3.2.2. The second objective is to test if relative preference weights can be ranked in order to inform the prioritizing of nearshore management planning and monitoring activities, including biological and socioeconomic indicators related to MPA performance. This objective is addressed in Section 3.2.2. The remaining analytic objectives are addressed by testing the effect of a number of factors on the variation in relative preferences weights across individuals and the groups they represent (Duke & Aull-Hyde, 2002; Strager & Rosenberger, 2006). The third objective is to test if relative preference weights can be grouped in order to reveal correlations with the resource use patterns of stakeholders. The fourth objective is to test if relative preference weights can be grouped in order to identify stakeholder groups of interest. The fifth objective is to test if relative preference weights can be grouped in order to better define the geographic market for various marine ecosystem services.

## 3.2. MATERIALS AND METHODS

### 3.2.1 Survey Design

I used data generated in Chapter 2 to develop a survey instrument to achieve the objectives listed in Section 3.1.1. This section describes the individual components of the survey.

#### *3.2.1.1 Preference Weight Solicitation*

I chose the method of paired comparisons as the weight solicitation technique. I chose the method of paired comparisons for two reasons. First, the method is particularly amenable to weighting multi-metric entities with incommensurate values such as ecosystem services (Chan et al., 2012; Chuenpagdee et al., 2010; Hanley et al., 1998; Naidoo & Adamowicz, 2005). Environmental values may overlap or be interconnected with each other, as well as having many incommensurate properties—especially with respect to ecosystem services, which provide multiple benefits valued for multiple reasons (Boyd & Krupnick, 2009; Chan et al., 2012). This complexity is especially evident when comparing cultural ecosystem services with more biological metrics, as well as comparing nonuse values with direct use values. For this reason, it is difficult to compare different services within the context of a single metric like dollar amounts, and multi-metric approaches are commonly advocated (Chan et al., 2012; Chee, 2004; Gatto & De Leo, 2000; Norton & Noonan, 2007; Spash, 2008; Spash, 2008). See Section 1.2.1.3 for a discussion of this topic.

The second benefit of choosing the method of paired comparisons is that a full paired comparison design can be condensed into an abbreviated pairwise design in order to reduce the cognitive burden on survey responses (Strager & Rosenberger, 2006). In an abbreviated format, all possible pairings of the criteria are not presented to the participant. Instead, pairs are sequentially assigned as A–B, B–C, C–D, etc. A complete ranking of criteria is based on the actual choices made and assuming transitive preferences. This assumption has been confirmed through a method of paired comparison (Peterson & Brown, 1998). In order to reduce issues of path dependency (Saaty, 1980), the initial criterion and the second criterion in each subsequent pair are randomly assigned. My design also randomizes the criteria, and in addition randomizes pairs (i.e., A–B, C–D, B–C, for example), in order to minimize the potential for anchoring bias.

A relative importance scale for measuring intensity of preferences was used in this survey. However, I employed a reduced form of the traditional nine nominal values to further reduce the cognitive burden of participants (see Strager & Rosenberger, 2006). Table 6 crosswalks the nine traditional values (Saaty, 1980) to the four intensity of preference nominal values used in the survey, including equal, somewhat prefer, prefer, and strongly prefer. Appendix A presents the survey instrument used in this study.

**Table 6.** Traditionally pairwise intensities and simplified choices used in this study

| Traditional pairwise intensities | Values | Simplified intensities | Values |
|---|---|---|---|
| Equal | 0 | Equal | 0 |
| Barely prefer | 1 | | |
| Weakly prefer | 2 | | |
| Moderately prefer | 3 | Somewhat prefer | 3 |
| Definitely prefer | 4 | | |
| Strongly prefer | 5 | Prefer | 5 |
| Very strongly prefer | 6 | | |
| Critically prefer | 7 | Strongly prefer | 7 |
| Absolutely prefer | 8 | | |

The simplified choices were used in this study based on the difficulty test respondents experienced in distinguishing between intensities with the 9-point traditional scale. The 4-point scaling system was adopted to reduce the cognitive burden.

#### *3.2.1.2 Grouping Variables*

A number of variables were included in the survey in order to generate groups. Included in the survey instrument was one grouping variable: a measurement of resource use patterns. Other grouping variables were derived through knowledge of survey respondents, including stakeholder category (75th Oregon Legislative Assembly, 2009) and location of residence. Each of these variables is discussed in turn.

The survey instrument derived resource use patterns by asking respondents to identify their "ocean-going activities" (see Appendix A). Survey questions asked in what ways respondents use or enjoy their local ocean resources, and how often. Measuring activity level as well as activity allows for further analysis of resource use intensity and skill level (Vaske et al., 2004). Activities were generalized from the results of focus groups held to develop the survey (see Section 3.2.1.4). Appendix A includes the resource use pattern questions included in the survey. Questions on resource use are included as grouping variables to test whether resource use determines preferences for ecosystem services. Confirming groupings and correlations would allow for more targeted monitoring efforts, such as collecting non-consumptive use data on one user group for an MSP action that is predicted to disproportionately affect associated ecosystem services. Furthermore, it would facilitate characterization of group-specific demand functions for survey items. This objective is analyzed in Section 3.3.3.

Other grouping variables were derived through knowledge of survey respondents, rather than via the survey instrument. Groups of interest were defined based on the nearshore management process in Oregon. Provisions guiding the marine reserve process in Oregon are in part provided in Oregon House Bill 3013 (75th Oregon Legislative Assembly, 2009), which stipulates that formation of "community teams" to consider the biological and socioeconomic information developed pursuant to the marine reserve process. These community teams must comprise "diverse and balanced stakeholder representation" (p. 2) that includes the following eight stakeholder categories: local government, recreational fishing industry, commercial fishing industry, nonfishing industry, recreationalists, conservation, coastal watershed councils, and relevant marine and avian scientists. As is discussed in the next section, participation in development of the survey instrument targeted members of these stakeholder groups in order to align with state standards. Information on the appropriateness of these groupings will similarly align with efforts to monitor these groups' preferences. This objective is analyzed in Section 3.3.3.

The second grouping variable derived from information on respondents is location of residence, which is categorized as either "coastal" or "non-coastal." Due to the sampling methodology (see Section 3.2.1.3), all non-coastal respondents reside in the Willamette Valley. I chose to include this data as a grouping variable for two reasons. The first is to test whether these two communities of place constitute different populations with different preferences for ecosystem service provision. The second is to test the spatial variability of individual relative preference weights. In order to conduct a thorough economic analysis of MSP in Oregon, it is important to begin to define the geographic scope of the market for individual ecosystem services. This objective is analyzed in Section 3.3.3.

Additional spatially-dependent hypotheses can also be tested with regard to the types of value primarily assigned to different ecosystem services. With regard to the geographic scope of the market, past economic modeling has concluded that use values for a particular natural resource decline with distance from that resource since the cost of using a resource increases with distance. This effect is called the *distance decay* of value (Hanley et al., 2003a). While this market characteristic applies to use values, the debate on distance decay of nonuse values is not settled (Bateman et al., 2006). Within the total economic value (TEV) framework, nonuse values consist of option, bequest, and existence values (Peterson & Swanson, 1987). Option values share some of the same properties as use values, including distance decay (Sutherland and Walsh 1985) because they refer to potential future use. Furthermore, option values may increase in response to improvements to resource quality in the form of realized latent demand (Bateman et al., 2006). Bequest values are not very constrained by physical dimensions (Peterson & Swanson, 1987), since they refer to the use or nonuse of future generations whose location is unknown.

Similarly, existence values do not necessarily directly correspond to proximity to a resource (Hanley et al., 2003a). An absence of distance decay for some environmental values is possibly illustrated by the fact that political support in Oregon for the establishment of marine protected areas (MPAs) extends statewide—outside of the geographic scope of regular users of Oregon's marine resources (The Oregonian, 2009). A distance decay of existence value related to the MPAs may exist, however, due to a number of indirect relationships. First, existence values could be indirectly related to distance insofar as knowledge of and familiarity with a resource can decrease with distance (Pate & Loomis, 1997; Sutherland & Walsh, 1985). Second, existence values may correlate with a dimension of cultural ownership (Bateman et al., 2006; Hanley, Schläpfer, & Spurgeon, 2003b) or other demographics. Lastly, users of a resource will generally hold higher values of all types than nonusers (Bateman et al., 2006).

With regard for these possible effects, I posit an additional hypothesis: relative preference weights for services providing existence value increase with distance from a resource. This hypothesis combines a possible absence of distance decay of existence values with distance decay of use values. It is therefore one of the hypotheses of this study that the mean rank of survey items designed to isolate existence value will be larger in the non-coastal group than the coastal group. The results of this hypothesis will inform whether it is appropriate to use a distance decay function for use values to define the entire geographic scope of the market for MPAs in Oregon, or whether doing so would undervalue the preservation of Oregon's marine ecosystems. This hypothesis is analyzed in Section 3.4.2.2.

#### *3.2.1.3 Survey administration*

Surveys were administered by individual mailings to participants of the focus groups organized for development and testing of the approach (Chapter 2), as well as stakeholders recruited to participate but were not able to. See Section 2.3.2for a discussion of the sampling methodology. The participants in this study represent a small, but not random, sample of stakeholders. See Section 4.1 for a description of the response rate and the demographic makeup of the sampled population. Also, see Section 5 for a discussion on the implications the sample size and methodology to the analytical conclusions.

## 3.3. ANALYSIS

This section presents a statistical analysis of final survey data with respect to the objectives in Section 3.1.1.

### 3.3.1 Preference Weight Calculation

For each respondent, aggregated individual preference weights for the 11 survey items were calculated using Criterium DecisionPlus software (Info Harvest, 2012) (Strager & Rosenberger, 2006). Preference weights imply a ranking of survey items. Calculation of consistency ratios—measures of consistent (transitive) preferences (Saaty, 1980)—is redundant with the abbreviated pairwise comparison format because transitivity is already assumed (Strager & Rosenberger, 2006). Nevertheless, I confirmed the assumption of transitivity by administering a pretest to a small convenience sample of participants that included both a full pairwise design and an abbreviated pairwise design. Responses were tested for consistency in rank order of preference weights across methods, and consistency ratios were calculated for the full pairwise design data.

The first test resulted in all but one survey holding consistency in rank order. The survey that differed was a result of a tie in the ranking of weights from the abbreviated pairwise design where the full pairwise design did not produce a tie. Preference weights generated by the abbreviated pairwise design have less resolution than those generated from the full pairwise design. This result also highlighted the study design issue of resolution and ties in preference weights. Ultimately, I chose the benefits of providing a less burdensome abbreviated design in the survey instrument over the benefits of increased resolution in data. I analytically treated tied ranks by assigning the average value of the ranks tied for (Friedman, 1937), although data transformed in this fashion have been shown to have nonlinear effects (Brockhoff, 2004). The second test resulted in sufficiently high consistency ratios for data from all but one survey. Upon investigation, I learned that particular respondent was confused by the tradeoff exercise because the ecological effects described by certain survey items were to his knowledge correlated. In an attempt to prevent similarly inconsistent results in the sample data, I included a disclaimer in the survey instructions to treat each survey item as independent, ecologically unrelated outcomes.

### 3.3.2 Confirmation of Grouping Variables

To determine if grouping variables identified populations with shared preferences (Bantayan & Bishop, 1998; Strager & Rosenberger, 2006), preference weights from the paired comparison exercises were analyzed using Friedman's Q statistic (a nonparametric, two-way analysis of variance by ranks statistic) (Friedman, 1937). Friedman's Q statistic is distributed as a Chi-square with $k - 1$ degrees of freedom. The data for calculation of this statistic were extracted from the ranks of the preference weights among participants within each group. The null hypothesis for the intra-group comparisons states that the preferences of members i in a group (y) represent a population ($P_y$). The alternative hypothesis states that intra-group members are not from the same population (i.e., preferences significantly differ across the group members).

### 3.3.3 Explanatory Effects on Preference Weights

The potential effects of grouping variables on preference weights for survey items were only analyzed for one variable: location. This potential effect was analyzed by comparing the rank order of survey items between the coastal and non-coastal groups. Similarly, in order to test the specific hypothesis of an inverse distance decay on ecosystem services that elicit existence value, the rank order of the survey item *The natural integrity of the marine ecosystem* is compared across the coastal and non-coastal groups.

## 3.4. RESULTS AND DISCUSSION

### 3.4.1 Survey Recruitment and Response

Survey participants were recruited and administered surveys according to the methodology described in Section 3.2.1.3. Results of the methodology are presented in Table 7. Those recruited were receptive to the study and I sent surveys to 50 individuals. As of September 28, 2012, 31 surveys had been returned (a 62% response rate).

**Table 7.** Survey sampling counts

| | Initially Contacted | Received Survey | Returned Survey[1] |
|---|---|---|---|
| N | 60 | 50 | 31 |
| Response % | | 83.33% | 62.00% |
| Notes:<br>[1]As of September 28, 2012 | | | |

Due to constraints on the number and range of individuals available for sampling, neither the initial recruitment nor the response data are evenly distributed across the grouping variables used for the analysis. Response data are presented by location (Table 7) and stakeholder category (Table 8). Also, resource use patterns could not be predicted prior to survey administration, so the response data is also unevenly distributed across this grouping variable (see Table 8).

**Table 8.** Survey responses by location

| | Coastal | Non-Coastal |
|---|---|---|
| N | 19 | 8 |
| % of Total | 70.37% | 29.63% |
| Notes:<br>1. Total does not sum to 31 because four surveys are unidentified with respect to this variable as of September 28, 2012 | | |

The response data represents coastal residents over non-coastal residents by a proportion of almost 2:1. This is mostly a reflection of three factors. First, there were two coastal study groups and one non-coastal study group sampled. Second, a slightly higher number of individuals from each coastal community (Redfish Rocks n=25, Otter Rock n=32) were recruited than from the non-coastal community (n=22). Lastly, coastal recruits returned surveys at a slightly higher rate.

The response data is also unevenly distributed across stakeholder categories. While it was the goal to recruit evenly from each category, this was not possible due to some stakeholders' being more available than others. In addition, different stakeholders were differently receptive to the survey. The two predominant stakeholder categories above, non-fishing industry and marine or avian scientist, are a result of disproportionately high response rates. A possible explanation for scientists' responding at a higher rate is that they are familiar with the institutions administering the survey (Oregon State University and the Oregon Department of Fish and Wildlife), and may relate to scientific studies.

Resource use across respondents is also uneven, as one might expect. The primary explanation for differences in resource use is the inherent differences in the associated activities. For example, nearly all respondents view the ocean from a distance, while less than 40 percent enjoy boating. Considering the relative ease of viewing the ocean as opposed to cost of boating, this is unsurprising. The question more relevant to this study is whether these resource uses constitute groups that determine preferences for ecosystem services. This question is analyzed in Section 3.4.2.5.

**Table 9.** Survey responses by stakeholder category

| | Local Govern-ment | Recreational Fishing Industry | Commercial Fishing Industry | Non-fishing Industry | Recreation-alist | Conser-vation | Watershed Council | Marine or Avian Scientist |
|---|---|---|---|---|---|---|---|---|
| N | 4 | 0 | 2 | 6 | 5 | 1 | 1 | 8 |
| % of Total | 14.81% | 0.00% | 7.41% | 22.22% | 18.52% | 3.70% | 3.70% | 29.63% |
| Notes:<br>1. Total does not sum to 31 because the surveys are still unidentified with respect to this variable. | | | | | | | | |

**Table 10.** Resource use descriptive statistics

| | Recreational fishing or harvesting | Commercial fishing or harvesting | Water sports | Beach going | Boating | Scientific or educational research | Stewardship activities | Sightseeing from a distance |
|---|---|---|---|---|---|---|---|---|
| N | 23 | 5 | 14 | 30 | 12 | 14 | 21 | 30 |
| % of Total | 74.19% | 16.13% | 45.16% | 96.77% | 38.71% | 45.16% | 67.74% | 96.77% |
| Mean # times /year | 12 | 51 | 53 | 50 | 27 | 15 | 25 | 156 |

### 3.4.2 Preference Weight Variability within Groups

Variability in preference weights were analyzed in order to determine if grouping variables delineated homogenous units. Variability in preference weights were analyzed using Friedman's Q statistic within four groups: the aggregate sample, location, stakeholder category, and resource use. Results of this statistic, as well as rank order and mean rank of preference weights for each survey item are presented for each group in Tables 10 through 13, respectively.

#### *3.4.2.1 Overall sample population*

Analysis on the aggregate group resulted in rejection of the null hypothesis of the Friedman's Q statistic. This result suggests that the overall sample does not constitute a single population, but rather that the preferences of respondents vary across the broad stakeholder community in Oregon. These results are expected based on the demographic, professional, and socioeconomic diversity of the sample. Therefore, some degree of grouping is necessary in order to characterize the distribution of preferences for ecosystem services. The rank order of aggregate preference weights should be considered within this context (Table 10). Also, it is likely that characterizing this distribution would be facilitated by collection of a larger, randomly drawn sample from the broader stakeholder community.

#### *3.4.2.2 Location*

Analysis on preference weights by location resulted in rejection of the null hypothesis of the Friedman's Q statistic within the coastal group, and failure to reject within the non-coastal group. While this result at first suggests that the coastal community of place does not constitute a homogenous population and the non-coastal community may, the more significant conclusion is that grouping stakeholders by location does not determine preferences. Therefore, it is necessary to use different grouping variables in order to characterize the distribution of preferences for ecosystem services. Also, it is likely that characterizing this distribution would be facilitated by collection of a larger, randomly drawn sample from each location.

#### *3.4.2.3 Distance decay*

The rank order of the aggregate preference weight on the survey item *The natural integrity of the marine ecosystem* decreased by one between the coastal and non-coastal groups, which suggests an inverse distance decay of existence value may exist within the market for MPAs in Oregon. This result, however, should be considered with regard to the fact that significant variation exists in preferences within the coastal group. A stronger conclusion could be drawn from a change in rank order between two groups that were independently confirmed to constitute homogenous and distinct populations. In fact, a linear regression on preference weights for *The natural integrity of the marine ecosystem* further demonstrates that a respondent's location is not associated with their preference weights (R square = .044, p = .268), although the power of this test is low due to the small sample size. In order to analyze with more confidence a possible distance decay in existence value for this survey item, a sufficiently large, randomized population of survey respondents should be sampled. In addition, respondents should be sampled across a larger distance from the coast to allow for more robust spatial analysis.

##### *3.4.2.4 Stakeholder category*

Analysis on preference weights by stakeholder category resulted in failure to reject the null hypothesis of the Friedman's Q statistic within all but the *Marine and avian scientist* groups. This result similarly suggests that grouping stakeholders by HB3013 category does not determine preferences. Therefore, it is necessary to use different grouping variables in order to characterize the distribution of preferences for ecosystem services. Also, considering the extremely small sample size within each stakeholder category, it is especially likely that characterizing this distribution would be facilitated by collection of a larger, randomly drawn sample from each sub-group.

##### *3.4.2.5 Resource use*

Analysis on preference weights by resource use patterns resulted in rejection of the null hypothesis of the Friedman's Q statistic within groups resulting from participation in each activity. This result similarly suggests that grouping by resource use in this way does not determine preferences. Therefore, it is necessary to use different grouping variables in order to characterize the distribution of preferences for ecosystem services. Also, it is likely that characterizing this distribution would be facilitated by collection of a larger, randomly drawn sample from each activity. It should be noted, however, that this grouping variable is unlike the others insofar as group membership is not mutually exclusive, and therefore responses cannot be treated as independent samples. Treatment of these features is discussed in Section 3.4.3.1.

#### 3.4.3 Survey Item Relative Ranking

The rank order of relative preference weights across stakeholders can be analyzed with regard to three measures in order to inform management. The first is the overall ranking of all 11 survey items within groups. As ordinal data, this ranking illustrates the ecological and socioeconomic priorities of respondents within each group. The second includes the relative preference weights assigned to each survey item. As cardinal data, these weights can be quantitatively applied to other data used in planning and decision-making, such as costs and benefits used in MSP decision matrices. The third measure is the variation in relative rankings and preference weights across groups. This information illustrates whether the priorities of different groups differ, and by how much.

The ordinal ranking of survey items in the non-grouped, aggregate sample (see Table 11 below) illustrate a few potential patterns with regard to the benefits that inclusive ecosystem services provide (see Tables 2 and 5). These patterns have implications for efforts to set state- or region-wide priorities in MSP. The top two survey items, *The number and size of fish and shellfish* and *Variety of sealife*, point to a prioritizing of the nonconsumptive use of fish and invertebrates over the consumptive use of fish and invertebrates, as well as the nonconsumptive use of seabirds and marine mammals. The next most highly ranked survey items, *The natural integrity of the marine ecosystem* and *The natural sustainability of the fish and shellfish stock*, imply a high value on the condition of whole system processes and fish populations. The lower ordinal rankings do not illustrate as many patterns with respect to benefits. However, some relationships are likely interesting to policy-makers in Oregon. For instance, *Outdoor recreation and leisure* is more highly valued, *Availability of fish and shellfish for harvest* has a relatively small value, and *Coastal culture and lifestyle* is ranked as least important.

These rankings are different for the coastal and non-coastal groups (see Table 12), suggesting a possible spatial-dependent variation in preference weights. Within the coastal group, a few of the lesser important items change position. Attendant preference weights, however, do not change much. Therefore, changes in rank order for these items in fact may not be very significant. The rank order within the non-coastal group does change more significantly (compared to both the coastal group and the aggregate group, which are similar). The largest change is in *The natural aesthetic of the seascape*, which increased in rank from 10 to 5 from the coastal to non-coastal groups. The second largest change is in *Outdoor recreation and leisure*, which increased from 5 to 2, and *Availability of fish and shellfish for harvest*, which decreased by the same amount—from 7 to 10. These shifts in priorities may not be surprising at first glance, considering general demographic differences between coastal and non-coastal communities. The more significant conclusion, however, is that rank order does change across different stakeholder groups. Such variation should be considered in future administration of the survey instrument developed in this study, as well as marine resource planners and policy makers.

**Table 11.** Aggregate (non-grouped) preference weight rank and intra-group variation

| RANK ORDER | SURVEY ITEM | MEAN RANK |
|---|---|---|
| 1 | Number and Size of Fish and Shellfish | 8.10 |
| 2 | Variety of Sealife | 7.40 |
| 3 | Natural Integrity of Marine Ecosystem | 7.30 |
| 4 | Natural Sustainability of Fish and Shellfish Stock | 6.63 |
| 5 | Outdoor Recreation and Leisure | 6.33 |
| 6 | Cleanliness of Ocean Water | 5.77 |
| 7 | Abundance of Seabirds | 5.45 |
| 7 | Availability of Fish and Shellfish for Harvest | 5.45 |
| 9 | Natural Aesthetic of the Seascape | 4.92 |
| 10 | Abundance of Marine Mammals | 4.87 |
| 11 | Coastal Culture and Lifestyle | 3.78 |
| **FRIEDMAN'S Q STATISTIC** | | |
| N | 30 | |
| Chi-Square | 49.719 | |
| df | 10 | |
| Sig. | 0.000 | |

**Table 12.** Preference weight rank and intra-group variation grouped by location

| Coastal | | | Non-Coastal | | |
|---|---|---|---|---|---|
| Rank Order | Survey item | Mean Rank | Rank Order | Survey item | Mean Rank |
| 1 | Number and Size of Fish and Shellfish | 7.90 | 1 | Number and Size of Fish and Shellfish | 8.50 |
| 2 | Variety of Sealife | 7.78 | 3 | Variety of Sealife | 6.65 |
| 3 | Natural Integrity of Marine Ecosystem | 7.65 | 4 | Natural Integrity of Marine Ecosystem | 6.60 |
| 4 | Natural Sustainability of Fish and Shellfish Stock | 6.85 | 6 | Natural Sustainability of Fish and Shellfish Stock | 6.20 |
| 5 | Outdoor Recreation and Leisure | 6.08 | 2 | Outdoor Recreation and Leisure | 6.85 |
| 6 | Cleanliness of Ocean Water | 5.98 | 8 | Cleanliness of Ocean Water | 5.35 |
| 7 | Availability of Fish and Shellfish for Harvest | 5.78 | 10 | Availability of Fish and Shellfish for Harvest | 4.80 |
| 8 | Abundance of Seabirds | 5.63 | 9 | Abundance of Seabirds | 5.10 |
| 9 | Abundance of Marine Mammals | 4.33 | 7 | Abundance of Marine Mammals | 5.95 |
| 10 | Natural Aesthetic of the Seascape | 4.15 | 5 | Natural Aesthetic of the Seascape | 6.45 |
| 11 | Coastal Culture and Lifestyle | 3.90 | 11 | Coastal Culture and Lifestyle | 3.55 |
| Friedman’s Q Statistic | | | | | |
| N | 20 | | 10 | | |
| Chi-Square | 41.52 | | 17.05 | | |
| df | 10 | | 10 | | |
| Sig. | 0.000 | | 0.073 | | |

**Table 13.** Summary of Friedman's Q statistic for within HB3013 stakeholder category grouping

| | Local Government | Recreational Fishing Industry | Commercial Fishing Industry | Nonfishin g Industry | Recreation-alist | Conserva tion | Coastal Watershed Council | Marine Avian Scientist |
|---|---|---|---|---|---|---|---|---|
| *N* | 3 | 0 | 2 | 7 | 5 | 3 | 1 | 8 |
| Statistic | 16.53 | n/a | 17.96 | 11.52 | 11.47 | 5.37 | n/a | 22.68 |
| df | 10 | 10 | 10 | 10 | 10 | 10 | n/a | 10 |
| Sig. | 0.085 | n/a | 0.056 | 0.318 | .322 | 0.865 | n/a | 0.012 |

**Table 14.** Summary of Friedman's Q statistic within resource use groupings

| | Recreational Fishing or Harvesting | Commercial Fishing or Harvesting | Water Sports | Beach Going | Boating | Scientific or Educational Research | Stewardship Activities | Sightseeing from a Distance |
|---|---|---|---|---|---|---|---|---|
| *N* | 20 | 5 | 14 | 27 | 12 | 14 | 20 | 20 |
| Statistic | 40.47 | 18.42 | 34.71 | 47.97 | 20.95 | 40.79 | 43.64 | 47.97 |
| df | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Sig. | 0.000 | 0.048 | 0.000 | 0.000 | 0.021 | 0.000 | 0.000 | 0.000 |

### 3.4.4 Resource Use

Unlike the other grouping variables in this study, resource use activities are not mutually exclusive and therefore cannot be treated as independent variables. Therefore, it is first necessary to describe potential relationships among these data in order to better characterize appropriate groupings. In order to do so, I analyze resource use data with respect to internal collinearities, as well as the potential for other grouping variables to act as confounding factors on the distribution of resource use patterns.

Possible positive correlations are tested for significance and presented below in Table 15. Variables displaying statistically significant correlations are further analyzed for reliability using Chronbach alpha statistic. Results are presented in Table 15. Chronbach alpha can be interpreted as a correlation; an alpha of .65 is generally accepted as sufficient to justify indexing of two variables. Using this criterion, the two resource use variables that correlate strongly enough to be indexed are Recreational fishing and harvesting and Boating. While neither activity is necessarily coupled, this result makes intuitive sense. It should be noted that Commercial fishing and harvesting did not correlate with Boating, suggesting that survey respondents interpreted the former as including a boating experience distinct from Boating as an activity.

**Table 15.** Correlations between number of days per year participating in resource use activities

| Variable 1 | Variable 2 | Correlation significance (two tailed) |
|---|---|---|
| Recreational fishing and harvesting | Boating | p = .001 |
| Recreational fishing and harvesting | Water sports | p = .001 |
| Sightseeing from a distance | Water sports | p = .762 |
| Water sports | Going to the beach | p = .015 |

**Table 16.** Reliability analysis of resource use variables

| Variable | Variable Total Correlation | Alpha If Item Deleted | Chronbach Alpha |
|---|---|---|---|
| Recreational fishing and harvesting | .720 | .499 | .626 |
| Water sports | .491 | .662 | |
| Boating | .466 | .498 | |
| Notes: Although there is some disagreement over the value of reliability estimates of Chronbach alpha for continuous data, these data are on the same scale (number of days per year). | | | |

The next step is to analyze the effect the other two grouping variables, location and stakeholder group, have on the distribution of resource use. These relationships are each analyzed with a multivariate analysis of covariance (MANCOVA), which includes Boating as a covariate. Results of the MANCOVA by location are presented in Table 17. It should be noted that similar MANCOVA tests on the binary resource use variable measuring whether or not respondents participated in activities did not result in any significant differences in variance across location or stakeholder group. This result suggests that non-coastal residents partake in similar resource use activities, but at a lesser intensity, presumably due to the larger travel cost associated with driving to the coast.

**Table 17.** Multivariate analysis of covariance of resource use by location

| Resource Use Variable | By Location[1] | | By Stakeholder Group[2] | |
|---|---|---|---|---|
| | Significance | Observed Power | Significance | Observed Power |
| Recreational fishing and harvesting | .012 | .733 | .156 | .536 |
| Commercial fishing and harvesting | .192 | .253 | .000 | 1.000 |
| Water sports | .160 | .287 | .000 | .995 |
| Going to the beach | .179 | .265 | .385 | .348 |
| Boating | .120 | .133 | .177 | .511 |
| Conducting scientific research or education | .242 | .211 | .403 | .338 |
| Participating in stewardship activities | .395 | .133 | .568 | .257 |
| Sightseeing from a distance | .001 | .964 | .012 | .878 |

Notes:
1. Multivariate tests were significant ($p = .002$)
2. Multivariate tests were significant ($p = .000$)
3. Treating Boating as a covariate did not influence the significance of either overall model, nor did it greatly influence the significance of any individual *F*-tests.

MANCOVA results suggest that location and stakeholder category may have a significant effect on the distribution of resource use patterns across respondents. Specifically, location has a significant effect on the number of times a year respondents engage in Recreational fishing and harvesting and Sightseeing from a distance. Also, stakeholder category has a significant effect on the number of times a year respondents engage in Commercial fishing and harvesting, Water sports, and Sightseeing from a distance. These relationships highlight variables that may confound efforts to quantify the effect of resource use patterns on relative preference weights for ecosystem services. These variables are not controlled for in this study. Rather, the potential implications of these results are discussed in Section 3.5.

## 3.5. CONCLUSION

This section presents concluding thoughts on the applicability of the survey instrument, the methods used to develop the survey and analyze survey results, the limitations of the analysis, potential policy applications of the survey and its outputs, and a discussion of future extensions of the survey.

### 3.5.1 Objectives

The overarching purpose of this chapter was to test the ability of the approach to inform nearshore management decision-making in Oregon by measuring and valuing marine ecosystem services. With respect to the objective of estimating relative preference weights for the 11 survey items generated by the implementation of the approach, the survey instrument was effective and generated internally consistent data relevant to MSP decision-making.

With respect to the objective of analyzing the variation in preference weights across groups, the grouping variables included in the survey, specifically resource use, may need revision. However, the appropriateness of grouping variables should, like the rest of the data, be considered in light of the small non-random sample population. Specifically, preferences vary across individual within most groupings, suggesting that the survey sample was not large enough to identify grouping variables that comprised populations. In order to fully characterize the distribution of preferences for ecosystem services across the overall stakeholder community, as well as within the groupings used in this study, an adequate sample would need to be randomly drawn for each group and the stakeholder community at large. Nevertheless, the analysis highlights a number of potential relationships to explore in future studies of the market for marine ecosystem services in Oregon.

### 3.5.2 Methods

While the abbreviated pairwise design generated internally consistent data, a full pairwise design might be considered to further increase the statistical power of the survey design. Preference weights generated by the abbreviated pairwise design have less resolution than those generated from the full pairwise design. Ultimately, I chose the benefits of providing a less burdensome abbreviated design in the survey instrument over the benefits of increased resolution in data. However, a different sampling methodology may provide an opportunity to administer a full design (i.e. 54 tradeoffs with 11 survey items) or an orthogonal design.

### 3.5.3 Limitations

The main limitation to the analysis conducted in this chapter is the size of the sample of survey respondents. Even in the case of a larger, random sample, however, the survey instrument is designed to generate a relatively narrow set of data. Survey items employed in the tradeoff exercise are the direct output of another implementation study. Conclusions drawn from this analysis should therefore be interpreted within the context of not just this study, but also that in Chapter 2.

### 3.5.4 Policy applications

In general, the survey developed in this chapter has the potential to be broadly applicable to decision-making regarding multiple use, complex systems like MPAs (Brown et al., 2001). Data resulting from this study could potentially be used to inform the creation, management, and monitoring of MPAs in Oregon by aiding decision-support, better defining the market for various marine ecosystem services, identifying stakeholder groups of interest, and prioritizing biological and socioeconomic indicators related to marine reserve performance.

One application of relative preference weights for marine ecosystem services is to incorporate aggregate preference scores decision matrices used in MSP. For example, resource management agencies in Oregon could use aggregate preference weights to adjust a cost-benefit analysis of provisioning related marine ecosystem services through MSP. Another application of relative preference weights for marine ecosystem services is to apply the aggregate rank order to inform the prioritizing of nearshore management planning and monitoring activities, including biological and socioeconomic indicators related to MPA performance. Studies with similar objectives have successfully combined incommensurate quantitative and qualitative information for decision-making to rank development scenarios on the basis of stakeholder values (K. Brown et al., 2001). Lastly, relative preference weights derived through similar methods have been integrated into spatial multi-criteria decision analysis scenarios (Strager & Rosenberger, 2006).

### 3.5.5 Future Extensions

Researchers interested in extending the development of this study could explore a number of possible survey modifications and applications. A potential modification could be the design of additional grouping variables based on other potential relationships between demand for ecosystem services and stakeholder demographics or attributes. Also, as discussed in Section 2.6.6, the set of survey items generated by the approach are structured so as to allow development of an attribute-based contingent valuation survey instrument. Lastly, potential exists to adopt or adapt the tradeoff exercise used in the survey instrument structured multi-criteria decision analysis exercises (Brown et al., 2001).

# CHAPTER 4

# A PERSPECTIVE ON DEVELOPMENT AND IMPLEMENTATION OF AN APPROACH FOR ANALYZING TRADEOFFS ACROSS MARINE ECOSYSTEM SERVICES

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## 4.1. INTRODUCTION

This chapter provides number of perspectives on the development and implementation of the approach. With respect to the validity and effectiveness of this study, the first section analyzes the design and characteristics of the approach for its ability to meet its goals and objectives. With respect to the value of the approach to policy-makers, natural resource managers, and researchers working to advance marine spatial planning (MSP) and marine ecosystem-based management (EBM), the second section analyzes the results of the study within the context of potential current and future applications. The next section discusses the limitations of the approach, and the last section provides potential future directions for additional development and application of the approach.

## 4.2. DESIGN AND CHARACTERISTICS OF THE APPROACH

The principal purpose of this study is to develop and test an approach for evaluating ecosystem service tradeoffs associated with MSP in Oregon. This approach was designed with specific criteria to meet certain objectives, which in turn determined the final product and its potential applications. The approach can therefore be analyzed on three levels: The first level pertains to policy contexts within which the approach was designed: the practice of MSP in Oregon and the principles and practices of EBM in the United States. These policies provide the criteria for the approach's design, the general objectives of the approach, and the criteria for meeting those objectives. The second level pertains to the analytic objective of the approach: to generate survey items of marine ecosystem services that can be used to evaluate the ecological and socioeconomic tradeoffs associated with MSP in Oregon. This level includes the theoretical requirements of those survey items and attendant methodological objectives. The third level is the application of these survey items within a tradeoff analysis to inform nearshore management decisions in Oregon. The practical and theoretical considerations on each of these levels, as well as the methods of achieving them, are discussed in turn below.

### 4.2.1 Policy Context for Approach Design

This study does not address all aspects of either EBM or MSP, but rather provides a tool to inform a specific application of MSP in accordance with EBM. Specifically, the criteria for designing this approach stem from the effort of the state of Oregon to develop a community-based method for evaluating the ecological and socioeconomic tradeoffs associated with MSP in state waters. As discussed in Chapter 1, MSP is a conceptually simple tool, and can therefore also be applied quite simply. As an EBM tool, however, MSP must meet a wide range of procedural and outcome-based objectives. The state of Oregon was interested in meeting two of those objectives: the conservation of provision of ecosystem services (McLeod & Lubchenco, 2005), and the consideration of common social values and preferences within a scientific understanding of the ecosystem (Crowder & Norse, 2008). The approach meets the first objective through the measurement and valuation of marine ecosystem services. Other applications include systematizing or organizing ecosystem services, quantifying ecosystem services, and mainstreaming of ecosystem services into social behavior or policy and management decisions (Nahlik et al., 2012). Implementation of the approach meets the second objective through engaging the stakeholder community in order to integrate ecological and economic analyses.

*4.2.1.1 Approach characteristics*

Before discussing the objectives of the approach, it is necessary to describe the approach in general. Nahlik et al. (2012) recommends a number of characteristics that should be incorporated into an ecosystem service assessment framework in order for it to be operational. The first characteristic is an ecosystem service definition and classification system that is systematic, complete, non-duplicative, and consistent and reproducible. The approach uses the definition of final ecosystem services: "…"components of nature, directly enjoyed, consumed, or used to yield human well-being" (Boyd & Banzhaf, 2007). As discussed in Section 2.1.1, this definition fits within ecological production theory, which itself provides a beneficiary-based classification system for the purposes of measuring, valuing, and communicating ecosystem services. As Nahlik et al. (2012) point out, this system has a number of advantages. First, it minimizes ambiguity and promotes repeatable identification of ecosystem services. Second, it avoids double-counting. Third, it encourages interdisciplinary research by integrating environmental and economic features. Fourth, identified ecosystem services are by definition understood by beneficiaries, which can include the public and broader stakeholder community. The approach developed in this study shares these features by virtue of the definition and classification system used. It should be noted, however, that these characteristics do not necessarily make the system operational. The effort to operationalize the system highlighted additional complexities that should be accounted for in future applications of the approach, which are discussed in Section 4.5.

The second recommended characteristic of an ecosystem assessment approach is that it be transdisciplinary, and as such should engage the shared efforts of natural and social scientists using theory that bridges their respective disciplines. The approach employs transdisciplinary study to define the structural linkages between survey items and ecological models, which include identification of bioindicators of ecosystem provision, as well as their inclusion in survey items. The third recommended characteristic is community engagement, including at the early stage of identifying ecosystem services. The approach engages stakeholder communities at precisely this point, as well as at a second point to further refine the presentation of ecosystem services in the stated-preference survey instrument. The third recommended characteristic is that a approach be policy-relevant, and information gained through the approach should improve policy management decisions. The approach was originally designed to meet the specific needs of marine resource management agencies in Oregon, and as a result, the outputs—survey items and associated bioindicators for monitoring—are relevant to the state's nearshore management decisions. The potential applications of these outputs are discussed further in Section 4.5.

*4.2.1.2 Approach Objectives*

The first objective of the approach, measurement and valuation of ecosystem services, must itself meet three objectives: the quantification and communication of the contribution of ecosystem services to human well-being; the evaluation of trade-offs between ecosystem services and between ecosystem services and "services generated through human efforts" (p. 28); and the inclusion of the value of ecosystem services in the relevant resource management decision making process (Nahlik et al., 2012). The approach fully meets each of these objectives. The first objective is met in two ways. The contribution of ecosystem services to human well-being is communicated through the process of stakeholder engagement used to generate the survey items, as well as through the survey items themselves. In fact, communicating the importance of ecosystem services to human well-being is a requirement of survey items generated by the approach (see Section 4.2.1). (It should also be noted that meeting this objective of the authors simultaneously satisfies the second overall objective of the approach stated above.) This contribution is then quantified via the identification and measurement of bioindicators of final ecosystem service provision. While this study only identified these bioindicators, their measurement through characterization of a more complete ecological production function is possible with the output available at this point (Kremen & Ostfeld, 2005).

The second objective of Nahlik et al. (2012) is met via the application of the approach to generate survey items of final ecosystem services appropriate for a tradeoff exercise. The final list of survey items (see Table 3) represented ecosystem services as strictly biophysical entities, as well as "cultural services," which some consider to be benefits because they are realized through the input of non-natural capital, and therefore Nahlik et al. (2012) would likely consider "services generated through human efforts." The third objective is met via employing theses survey items in a paired comparison tradeoff exercise to generate relative preference weights for inclusion in the nearshore management decisions of the state of Oregon.

### 4.2.2 Survey Items of Marine Ecosystem Services

The second level on which the study can be analyzed pertains to the analytic objective of the approach: to generate survey items of marine ecosystem services that can be used to evaluate the ecological and socioeconomic tradeoffs associated with marine spatial planning in Oregon. In order to achieve this objective, survey items were required to meet the following theoretical requirements: link attributes of ecological models and ecosystem services that provide utility to respondents; be appropriate for economic valuation in that they are unambiguous and quantitatively commensurate with neoclassical utility models used for valuation, and; provide information that is meaningful, comprehensive, and comprehensible to non-scientist survey respondents. In order to derive survey items that meet these requirements, the study had four methodological objectives: 1) Identify final ecosystem services valued by coastal resource stakeholders in Oregon; 2) Define structural linkages between final ecosystem services and bioindicators of their provision; 3) Develop survey items of final ecosystem services appropriate for stated-preference valuation, and; 4) Test survey items for their ability to meet stated criteria. This section discusses these general objectives.

#### *4.2.2.1 Identifying ecosystem services*

I identified final ecosystem services valued by coastal resource stakeholders in Oregon through direct questioning during focus group meetings. This methodology is described in Section 2.3.2. Reliance on stakeholder engagement to identify and characterize ecosystem services stems from the ecosystem service definition and classification system used (see Section 4.2.1.2), which requires that ecosystem services be defined by "backing out" from associated benefits as described by ecosystem service beneficiaries. The approach was operationalized successfully, although many lessons were learned about how to effectively engage stakeholders for this purpose. See Section 4.3.2 for a discussion of this topic.

#### *4.2.2.2 Identifying bioindicators*

The requirement of this study that survey items link attributes of ecological models and ecosystem services that provide utility to respondents was achieved through identifying bioindicators of ecosystem service provision and integrating those bioindicators into the final survey items. Bioindicators were indentified by characterizing the provision of ecosystem services via SPUs/ESPs and their functional efficiency measures.

#### *4.2.2.3 Developing survey items*

In order to for survey items to be commensurate with economic utility models, survey items are structured to solicit relative preference weights through a trade-off exercise. Stated preference surveys derive respondents' weights by scaling answers according to a metric of preference (Brown, 2003). The approach generates survey items appropriate for a method of paired comparisons, which generates weights on a cardinal scale. See Section 1.2.5.2 for a discussion of why a cardinal scale is most appropriate for this approach. In order for survey items to provide information that is meaningful, comprehensive, and comprehensible to respondents, survey items were initially structured and phrased with regard to a number of considerations. First, qualitative language from the first focus group meetings revealing participants' understanding of ecological relationships and their utility functions, including the connection between benefits and services, were included in survey items to ensure their meaningfulness. As discussed in Section 1.2.3.2, these considerations primarily influenced the degree of differentiation used to present survey items. Second, the full set of final ecosystem services identified in the focus group meetings was included in survey items to ensure they are comprehensive. Third, initial phrasing of survey items included not just a statement of inclusive ecosystem services and bioindicators but also statements of what those metrics mean to ensure they are comprehensible.

#### *4.2.2.4 Testing survey items*

Survey items were tested through a second focus group meeting in which participants were asked to react to the design of each survey item with respect to the above criteria. See Section 2.3.2 for a discussion of this methodology, as well as a list of questions asked participants.

### 4.2.3 Tradeoff Analysis

The third level on which the study can be analyzed pertains to the application of these survey items within a tradeoff analysis to inform MSP decision making in Oregon. The tradeoff exercise employed in implementation of the approach generated relative preference weights for each survey item, which indicates the ordinal position of the items, as well as approximates an interval scale measure of preference, revealing the sizes of the intervals between items. Relative preference weights for survey items of final ecosystem services can be applied to nearshore management decisions in a number of ways. The first is as weights in decision matrices used in marine spatial planning. The second is as ranks to inform the prioritizing of planning and monitoring activities. These data can be incorporated into decision making in the aggregate or with respect to the characteristics of respondents. The applicability of this data to the specific management needs of the State of Oregon is discussed in more detail in the following sections.

## 4.3. STUDY RESULTS

Results of this study provide insight into the values and preferences of marine resource stakeholders in Oregon, which have implications for local nearshore management decision-making. Also, as marine reserves continue to be established in state waters, the approach and lessons learned from its application can guide future ecosystem service assessment and valuation studies in Oregon. This section discusses these two topics in turn.

### 4.3.1 Survey Data

The survey instrument designed in this study generated relative preference weights for 11 survey items representing 24 ecosystem services and bioindicators of their provision. Results of the statistical analysis of resulting preference weights provide a number of insights. First, the rank order of survey items in the aggregate and within coastal and non-coastal communities illustrates the priorities of different stakeholder communities with regard to the provision of ecosystem services from the marine environment. Specifically, the top two survey items for the aggregate population, *The number and size of fish and shellfish* and *Variety of sealife*, point to a prioritizing of the nonconsumptive use of fish and invertebrates over the consumptive use of fish and invertebrates, as well as the nonconsumptive use of seabirds and marine mammals. The next most highly ranked survey items, *The natural integrity of the marine ecosystem* and *The natural sustainability of the fish and shellfish stock*, imply a high value on the condition of whole system processes and fish populations. The lower ordinal rankings do not illustrate as many patterns with respect to benefits. However, some relationships are likely interesting to policy-makers in Oregon. For instance, *Outdoor recreation and leisure* is more highly valued, *Availability of fish and shellfish for harvest* has a relatively small value, and *Coastal culture and lifestyle* is ranked as least important.

The survey results also demonstrate that these rankings are different for the coastal and non-coastal groups (see Table 12), suggesting a possible spatial-dependent variation in preference weights. Specifically, the ranking of the item *The natural aesthetic of the seascape* increased in rank from 10 to 5 from the coastal to non-coastal groups, which was the largest change between groups. The second largest change is in *Outdoor recreation and leisure*, which increased from 5 to 2, and *Availability of fish and shellfish for harvest*, which decreased by the same amount—from 7 to 10. These shifts in priorities may not be surprising at first glance, considering general demographic differences between coastal and non-coastal communities. The more significant conclusion, however, is that rank order does change across different stakeholder groups. Such variation should be considered in future administration of the survey instrument developed in this study, as well as marine resource planners and policy makers.

The second insight provided by survey results is that relative preference weights for marine ecosystem services are heterogeneous within and across many of the groups defined by the grouping variables in the survey. Capturing the variations in stakeholder preferences is important when developing policies that affect different stakeholder groups. Thus, when implementing the survey instrument, I suggest random sampling of stakeholders stratified by location, affiliation, and resource use. Furthermore, a sufficiently large sample is necessary to allow for a robust analysis of variation in preference weights in the aggregate and across groups. With additional samples to increase confidence, managers and policy makers would be able to identify specific demographics within which people's preferences for the outcomes of MSP are different. Such information would allow for more informed decisions regarding spatial planning with known effects across space and time.

### 4.3.2 Implementation study methods

The approach developed in this study can be operationalized using methodologies other than those used in the implementation study documented in Chapter 2. In order to meet the research needs of the State of Oregon, however, application of the approach specifically used focus groups comprised of members of the stakeholder community. While the group dynamics and challenge of moderating may have complicated the identification of final ecosystem services, a wealth of valuable qualitative information was gathered on the marine resource stakeholder community in Oregon. In particular, it became clear throughout the process of identifying final ecosystem services that focus group participants gravitated towards expressing the multi-dimensional nature of ecosystem services. Participants readily identified these values because they felt a strong yet irreducible identity with the culture of the Oregon coast. Their descriptions of this feeling were often nebulous, romanticized, and not directly attributable to any natural features or qualities over others. As a result, participants at times resisted the task of extricating discrete ecosystem services and gravitated towards describing social and psychological benefits.

I addressed these challenges in two ways. First, I devised ecologically indistinct services when possible (e.g. *Support of socially valued lifestyle*). Second, I developed a methodology and organized extra focus groups to characterize a survey item for an ecosystem service representing whole system processes that elicits pure existence value. As discussed in Section 1.2.3.4, these measures were not just an offshoot of the original approach, but rather a means to address a limitation of the ecosystem service definition and classification system that served as the foundation for the approach. In this sense, the community-based criteria for implementation of the approach at most lead to an expansion of the approach. At the least, this development allowed me to account for diverse kinds of values, which is especially important when doing community-based work because there are diverse stakeholders and perspectives.

Similarly, the diversity of perspectives complicated but enhanced the process of testing survey items for their ability to meet the theoretical requirements outlined in Section 4.1.2.1. This step in the approach did not allow for a systematic analysis of bias, or how stakeholders understand the environment, or what stakeholder find meaningful. This step did, however, reveal certain metrics that were more important than others to the sample, such as community-level bioindicators over population-level bioindicators.

## 4.4. STUDY LIMITATIONS

This section discusses the limitations of the methods and conclusions employed in this study, as well as the implications of these limitations.

### 4.4.1 Approach development

An inherent limitation to the approach developed in this study relates to the topic of the multi-dimensional nature of ecosystem service values discussed in Chan et al. (2012). The authors note that many of the least tangible values (e.g., existence value elicited by ecosystem integrity) are also multi-dimensional and have incommensurate properties, and therefore challenge current economic assumptions and valuation methods. Furthermore, the authors note that attempts on the part of ecosystem service researchers to develop universal are noble, but inherently contradictory.

Specifically, some classes of value are incommensurate and therefore not amenable to tradeoffs in analytical approaches such as cost–benefit or risk assessment. This complication highlights the limitations of the approach developed in this study. While it is appropriate for generating metrics that will be valued via multi-criteria methods, those same metrics do not lend themselves to aggregation across the same dimension.

### 4.4.2 Implementation study

An operational limitation to the approach is that it requires an ecosystem service beneficiary as the analytic starting point. While this condition matched principles and practices of EBM that set the general criteria for the approach, many ecosystem service assessments start with an analyst, rather than a stakeholder. Similarly, many ecosystem service assessments start analytically with a biological metric or indicator and seek a way to relate that metric to an ecosystem service, and then relate that ecosystem service to the public. The ESP/SPU approach can not be applied under these constraints and with these objectives, so a different production function must be designed. Figure 10 below depicts a method of "backing into" survey item descriptions from the starting point of a bioindicator. This production function employs the levels of information discussed by Schiller et al. (2001) as part of a "common language" approach to communicating ecological indicators.

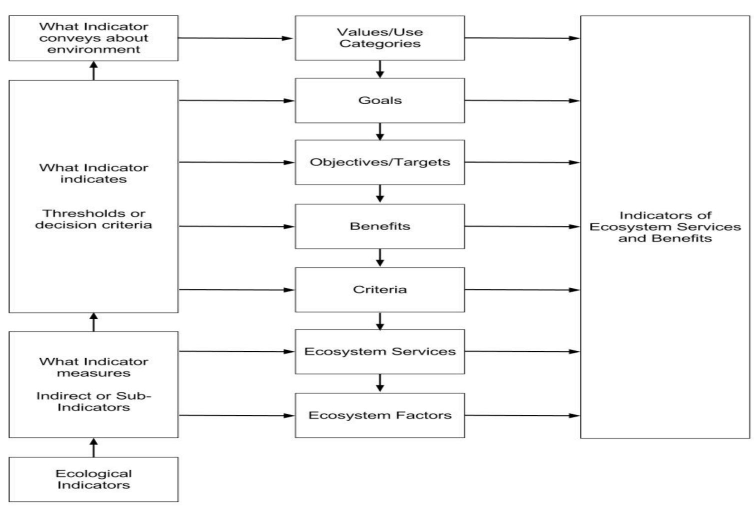


**Figure 10.** Common language production function

This production function employs the levels of information discussed by Schiller et al. (2001) as part of a "common language" approach to communicating ecological indicators.

## 4.5. POLICY APPLICATIONS AND FUTURE DIRECTIONS

In general, data resulting from this study can be used to inform the creation, management, and monitoring of MPAs in Oregon by aiding decision-support, better defining the market for various marine ecosystem services, identifying stakeholder groups of interest, and prioritizing biological and socioeconomic indicators related to marine reserve performance. This section discusses areas for policy application of methods and results, and areas for further development and research.

Tradeoff exercises provide a basis for examining which MSP scenarios and outcomes are optimal in terms of providing a level and combination of ecosystem services that society finds valuable. This approach provides those values in the form of relative preference weights. Relative preference weights for survey items of final ecosystem services can be applied to nearshore management decisions in a number of ways. The first is as weights in decision matrices used in marine spatial planning. The second is as ranks to inform the prioritizing of planning and monitoring activities. These data can be incorporated into decision making in the aggregate or with respect to the characteristics of respondents.

A unique aspect of the approach, however, is that it not only generates relative preference weights for ecosystem services, but it links those values to bioindicators used to monitor changes in those services over time. This connection allows for more advanced tradeoff analyses to be developed. It should be a priority of researchers to build upon this study with this goal. For example, ecologists could improve the modeling of the provision of the ecosystem services generated by this approach in order to generate an production possibility frontier, while economists could refine measurement of demand for the same ecosystem services in order to generate indifference curves. From these two functions, efficiency frontiers can be generated in order to identify management options that provide for the optimal delivery of any range of ecosystem services (Lester et al., 2012).

As marine reserves continue to be established in Oregon state waters, the approach and lessons learned from its application can guide future ecosystem service assessment and valuation studies in Oregon. The approach is designed to be broadly applicable to any MSP scenario, and future applications could generate data that complements or modifies the results of this study. If it were the interest of researchers to avoid applying the approach from scratch, a potential area for further development and research would be methods for scaling the approach up (or down). Researchers would have to consider which metrics are most amenable to scaling—the bioindicators for biological monitoring or the survey items for a broader sample.

Results of the application of the approach allow for further development and research into the ecological production function underlying the provision of final ecosystem services. ESPs and efficiency measures (bioindicators) identified in this analysis provide a basis for estimating functional contributions to the provision of final ecosystem services. Concurrent to further characterization of an ecological production function could be development of a valuation instrument that more closely links ecosystem functions to economic value via an attribute-based choice model (Llorente-Garcia et al., 2011; Sanchirico & Mumby, 2009).

**4.6 FINAL THOUGHTS**

Hopefully this study will contribute to a range of emerging efforts to improve the stewardship of our shared marine resources. On the management side, the approach developed in this study holds great promise for implementing MSP in accordance with the principles of EBM. On the research side, work like this has the potential to contribute to the effort to find consensus on an approach and classification system to standardize future final ecosystem service valuation studies conducted by researchers in natural resource economics. As noted by Nahlik et al. (2012), few researchers have developed and applied an operational ecosystem service assessment approach based on the same theory and methods as this one (Ringold et al., 2009). Further development and application of the approach developed and tested in this study could therefore contribute to ecosystem-based MSP in Oregon and elsewhere, as well as advances in ecological and natural resource economics.

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# APPENDIX

# Oregon Marine Protected Areas Survey

A cooperative survey developed by:

| Oregon Department of Fish and Wildlife | Oregon State University | Oregon Sea Grant |
|---|---|---|
| OREGON Fish & Wildlife | OSU Oregon State UNIVERSITY | Sea Grant Oregon |

THANK YOU FOR PARTICIPATING IN THIS IMPORTANT SURVEY!

**PLEASE READ ALL THE INFORMATION IN THIS SURVEY CAREFULLY BEFORE ANSWERING QUESTIONS**

### WHAT IS THIS SURVEY ABOUT?

This survey asks for your perspective on environmental, social, and economic aspects of Oregon's coast that may change as a result of coastal management policies.

### WHAT SORT OF POLICIES?

Coastal and marine resource management in Oregon addresses a range of policies—from residential development to renewable energy. One policy in particular has provided the context for this survey: protected areas, such as "marine reserves" and "marine protected areas."

### WHAT ARE MARINE RESERVES AND PROTECTED AREAS?

Marine reserves and marine protected areas (together referred to in the survey as "protected areas") are sections of the ocean zoned to protect specific marine resources from direct human impacts. Within protected areas, "extractive activities" and new developments are prohibited fully (in the case of marine reserves) or partially (in the case of marine protected areas). Extractive activities are defined as "fishing, hunting and harvesting of shellfish, other invertebrates, kelp and seaweed."

All other non-extractive activities not having "a negative impact on marine habitats and biodiversity protected within the site," such as diving and surfing, for example, are allowed within protected areas.

Currently, two marine reserves and one marine protected area have been established in Oregon (see below), three others are scheduled to be established over the next two years, and up to four more are under discussion.

### CURRENT MARINE RESERVES AND PROTECTED AREAS

| Otter Rock Marine Reserve<br>(north of Newport, OR) | Redfish Rocks Marine Reserve<br>(Port Orford, OR) |
|---|---|
|  |  |

You can find more information on protected areas and nearshore management online @ www.oregonocean.info.

**HOW TO TAKE THIS SURVEY**

This survey contains three parts:

1. The first (1st) part is called an "opinion survey" and starts on page 4. It consists of questions about your opinion of protected areas in Oregon and the environment in general.

2. The second (2nd) part is called a "comparison survey" and starts on page 6. It involves comparing different environmental, social, and economic aspects that may change as a result of coastal management, such as the establishment of protected areas.

3. The third (3rd) part is called a "demographic survey" and starts on page 12. It asks for some demographic information describing you.

Each survey begins with mini-instructions. Please read these instructions carefully before answering the surveys.

Please answer all surveys from YOUR PERSPECTIVE ONLY. We are interested in only your experiences and what is important to you.

THANK YOU FOR YOUR PARTICIPATION! ENJOY

# OPINION SURVEY

This 1st part of the survey is what is called an "opinion survey." This survey includes questions about your familiarity with and opinion about the marine environment and its management.

These questions ask if and how you expect the establishment of marine protected areas in Oregon to affect the welfare of you and your community.

| | (Please check one) | | | |
|---|---|---|---|---|
| As protected areas are established in Oregon, how do you expect the following to be affected? | Increase | Stay the Same | Decrease | Not Sure |
| 1. Your household's economic welfare:<br>• Income<br>• Employment<br>• Property value, etc. | ☐ | ☐ | ☐ | ☐ |
| 2. Your community's economic welfare:<br>• Community income<br>• Community employment<br>• Community property values<br>• Tax revenues<br>• Business and industry revenues<br>• Development<br>• Visitation and tourism, etc. | ☐ | ☐ | ☐ | ☐ |
| 3. Your community's social and cultural welfare:<br>• Cultural identity<br>• Level of education and awareness<br>• State visibility and publicity<br>• Social relations<br>• Connection to other communities in Oregon<br>• Attractiveness of your community as a place to live, etc. | ☐ | ☐ | ☐ | ☐ |

## OPINION SURVEY

These questions ask if and how you expect the establishment of marine protected areas in Oregon to affect the welfare of you and your community.

| | (Please check one) | | | |
|---|---|---|---|---|
| As protected areas are established in Oregon, how do you expect the following to be affected? | Increase | Stay the Same | Decrease | Not Sure |
| 4. Your personal welfare:<br>• Leisure and recreation<br>• Inspiration<br>• Discovery<br>• Spirituality<br>• Independence and self-sufficiency<br>• Security, etc. | ☐ | ☐ | ☐ | ☐ |

These questions ask about your ocean-going activities on the Oregon coast.

| | In what ways do you use or enjoy your local ocean resources?<br><br>(Please check all that apply) | On average, how many times per year do you partake in this activity?<br><br>(Please provide a number) |
|---|---|---|
| 5. Recreational fishing or harvesting:<br>• Fish and/or shellfish<br>• Plants<br>• Algae | ☐ | ________ |
| 6. Commercial fishing or harvesting:<br>• Fish and/or shellfish<br>• Plants<br>• Algae | ☐ | ________ |
| 7. Water sports:<br>• Surfing<br>• SCUBA diving<br>• Kayaking<br>• Swimming, etc. | ☐ | ________ |

## OPINION SURVEY

These questions ask about your ocean-going activities on the Oregon coast.

| | In what ways do you use or enjoy your local ocean resources?<br><br>(Please check all that apply) | On average, how many times per year do you partake in this activity?<br><br>(Please provide a number) |
|---|---|---|
| 8. Beach going:<br>• Picnics<br>• Exploring tide pools<br>• Flying kites, etc. | ☐ | ______ |
| 9. Boating | ☐ | ______ |
| 10. Scientific or educational research | ☐ | ______ |
| 11. Stewardship activities:<br>• Beach cleanups<br>• Volunteer projects, etc. | ☐ | ______ |
| 12. Sightseeing from a distance:<br>• Enjoying the sunset<br>• Landscape photography, etc. | ☐ | ______ |

THANKS! NOW ON TO PART 2, THE COMPARISON SURVEY

## COMPARISON SURVEY

This 2nd part of the survey is what is called a "comparison survey." This survey presents "aspects" representing different environmental, social, and economic aspects that may change as a result of coastal management, and asks you to say how important those aspects are to you compared to others.

Each aspect will appear as seen below:

| | | |
|---|---|---|
| ***The variety of sealife*** | ← | The title of the aspect |
| This aspect represents the range of fish, shellfish, marine mammal, and plant and algae species *inside* protected areas. An increase in this aspect means uncommon or previously unseen plant or animal species are more commonly present and visible. | ← | A more detailed description of what the aspect involves. |

Eleven such "aspects" will be presented side-by-side, and you will be asked to mark whether you prefer an increase in one aspect more than the other, and by what relative degree.

The side-by-side comparisons will appear as seen below. To mark your answer, simply fill in <u>one</u> circle on the scale that matches your personal preference.

For example, the below choice says you "somewhat prefer" an increase in "The Number and Size of Fish and Shellfish" over an increase in "The Abundance of Seabirds."

| An increase in... | Strongly prefer | Prefer | Somewhat | Equal | Somewhat | Prefer | Strongly prefer | An increase in... |
|---|---|---|---|---|---|---|---|---|
| ***The number and size of fish and shellfish*** | | | | | | | | ***The abundance of seabirds*** |
| This aspect represents the natural production of all fish and shellfish (harvested and non-harvested species) *inside* protected areas. An increase in this aspect means more and larger fish, crabs, sea stars, and anemones, for example, are present and visible. | o | o | • | o | o | o | o | This aspect represents the natural production of seabirds *inside* protected areas. An increase in this aspect means more seabirds are present and visible in flight or on the rocks or water inside protected areas. |

## COMPARISON SURVEY

Please note: Some of the aspects are environmentally related, and an increase in one may occur along with an increase in the other. For the purposes of this exercise, however, treat each aspect as an independent outcome and focus on which you would prefer to see increase.

So, for example, birds eat fish and therefore an increase in "The Number and Size of Fish and Shellfish" may eventually lead to an increase "The Abundance of Seabirds." However, if you are an avid bird watcher but not much of a SCUBA diver, you would prefer to see seabirds when you go to the beach, rather than fish and shellfish. In that case, you would mark that you prefer an increase in "The Abundance of Seabirds," even though the abundance of seabirds could increase via an increase in fish and shellfish.

Please answer this survey from YOUR PERSPECTIVE ONLY. We are interested in only your experiences and what is important to you.

This is the end of the instructions.

The comparison survey starts on the next page

## COMPARISON SURVEY

| An increase in… | Strongly prefer | Prefer | Somewhat prefer | Equal | Somewhat prefer | Prefer | Strongly prefer | An increase in… |
|---|---|---|---|---|---|---|---|---|
| ***Areas for outdoor recreation and leisure***<br>This aspect represents the amount of areas suitable and available for outdoor recreation and leisure *inside or adjacent to* protected areas. An increase in this aspect means more beach area, tide pools with more sealife, and areas used for water sports (e.g. kayaking, diving, surfing). | O | O | O | O | O | O | O | ***The natural aesthetic of the seascape***<br>This aspect represents the natural formation of coastal "scenery" *inside* protected areas. An increase in this aspect means a greater amount of areas displaying the natural features and dynamics that Oregonians find interesting, fascinating, or awe inspiring, such as forceful waves, rocky formations colonized by plants and animals, and kelp forests and intertidal plants. |
| | | | | | | | | |
| ***The cleanliness of coastal waters***<br>This aspect represents coastal water quality (*inside and outside* protected areas) for human contact and consumption of local seafood. An increase in this aspect means less biological and chemical waste in the water and in the organisms that live in it. | O | O | O | O | O | O | O | ***The number and size of fish and shellfish***<br>This aspect represents the natural production of all fish and shellfish (harvested and non-harvested species) *inside* protected areas. An increase in this aspect means more and larger fish, crabs, sea stars, and anemones, for example, are present and visible. |
| | | | | | | | | |
| ***The NATURAL SUSTAINABILITY of the local fish and shellfish stock***<br>This aspect represents the natural ability of harvested fish and shellfish populations *outside* protected areas to persist into the long-term future. An increase in this aspect means harvested stocks are more resilient to fishing or natural disturbance, and are more able to reproductively replace individuals. | O | O | O | O | O | O | O | ***Areas for outdoor recreation and leisure***<br>This aspect represents the amount of areas suitable and available for outdoor recreation and leisure *inside or adjacent to* protected areas. An increase in this aspect means more beach area, tide pools with more sealife, and areas used for water sports (e.g. kayaking, diving, surfing). |
| ***The variety of sealife***<br>This aspect represents the range of species of fish, shellfish, marine mammals, and plants and algae *inside* protected areas. An increase in this aspect means uncommon or previously unseen plants or animal species | O | O | O | O | O | O | O | ***The abundance of seabirds***<br>This aspect represents the natural production of seabirds *inside* protected areas. An increase in this aspect means more seabirds are present and visible in flight or on the rocks or water. |

## COMPARISON SURVEY

| An increase in… | Strongly prefer | Prefer | Somewhat prefer | Equal | Somewhat prefer | Prefer | Strongly prefer | An increase in… |
|---|---|---|---|---|---|---|---|---|
| are more commonly present and visible. | | | | | | | | |
| **The abundance of marine mammals**<br>This aspect represents the natural production of marine mammals *inside* protected areas. An increase in this aspect means a greater number of Pacific harbor seals, California sea lions, and grey whales, for example, present and visible. | o | o | o | o | o | o | o | **The natural integrity of the marine ecosystem**<br>This aspect represents the ability of the marine ecosystem (*inside and outside* of protected areas) to self-organize and support a mature, rich community of organisms. An increase in this aspect means organism populations and interactions (such as the food web) naturally become more functional and resilient. |
| **The natural integrity of the marine ecosystem**<br>This aspect represents the ability of the marine ecosystem (*inside and outside* of protected areas) to self-organize and support a mature, rich community of organisms. An increase in this aspect means organism populations and interactions (such as the food web) naturally become more functional and resilient. | o | o | o | o | o | o | o | **The cleanliness of coastal waters**<br>This aspect represents coastal water quality (*inside and outside* protected areas) for human contact and consumption of local seafood. An increase in this aspect means less biological and chemical waste in the water and in the organisms that live in it. |
| **The coastal culture and lifestyle**<br>This aspect represents the vitality of the culture and lifestyle that Oregonians consider characteristic of the coast. An increase in this aspect means that coastal communities exhibit a stronger economic, social, and cultural connection to the ocean, and there is more ocean-based tourism, research and education, and stewardship opportunities, for example. | o | o | o | o | o | o | o | **The availability of fish and shellfish for harvest**<br>This aspect represents the natural production of harvestable fish and shellfish *outside* protected areas. An increase in this aspect means an increase in the stock of legal-size fish and shellfish of those species available for commercial and recreational harvest. |

## COMPARISON SURVEY

| An increase in… | Strongly prefer | Prefer | Somewhat prefer | Equal | Somewhat prefer | Prefer | Strongly prefer | An increase in… |
|---|---|---|---|---|---|---|---|---|
| ***The abundance of seabirds***<br>This aspect represents the natural production of seabirds *inside* protected areas. An increase in this aspect means more seabirds are present and visible in flight or on the rocks or water. | O | O | O | O | O | O | O | ***The NATURAL SUSTAINABILITY of the local fish and shellfish stock***<br>This aspect represents the natural ability of harvested fish and shellfish populations *outside* protected areas to persist into the long-term future. An increase in this aspect means harvested stocks are more resilient to fishing or natural disturbance, and are more able to reproductively replace individuals. |
| | | | | | | | | |
| ***The natural aesthetic of the seascape***<br>This aspect represents the natural formation of coastal "scenery" *inside* protected areas. An increase in this aspect means a greater amount of areas displaying the natural features and dynamics that Oregonians find interesting, fascinating, or awe inspiring, such as forceful waves, rocky formations colonized by plants and animals, and kelp forests and intertidal plants. | O | O | O | O | O | O | O | ***The coastal culture and lifestyle***<br>This aspect represents the vitality of the culture and lifestyle that Oregonians consider characteristic of the coast. An increase in this aspect means that coastal communities exhibit a stronger economic, social, and cultural connection to the ocean, and there is more ocean-based tourism, research and education, and stewardship opportunities, for example. |
| ***The availability of fish and shellfish for harvest***<br>This aspect represents the natural production of harvestable fish and shellfish *outside* protected areas. An increase in this aspect means an increase in the stock of legal-size fish and shellfish of those species available for commercial and recreational harvest. | O | O | O | O | O | O | O | ***The abundance of marine mammals***<br>This aspect represents the natural production of marine mammals *inside* protected areas. An increase in this aspect means a greater number of Pacific harbor seals, California sea lions, and grey whales, for example, present and visible. |

THANKS! NOW ON TO PART 3, THE DEMOGRAPHIC SURVEY.

ALMOST DONE…

# DEMOGRAPHIC SURVEY

This 3rd part of the survey is called a "demographic survey" and is designed to give us a better picture of you as a person.

1. What year were you born in? ____________

2. Including yourself, how many adults and children currently live in your household?

   ______ adults (18 years or older)
   ______ children

3. How many years have you been living in your current community? _____ years

4. Which of the following indicates your level of education? (check one)

   - ☐ 8th grade or less
   - ☐ 9th to 11th grade
   - ☐ 12th grade (high school graduate)
   - ☐ 13-15 years (some college)
   - ☐ 16 years (college graduate)
   - ☐ 17+ years (some graduate work)
   - ☐ Masters, Doctoral, or Professional Degree

5. Which of the following best describes your household income before taxes?

   - ☐ Less than $15,000
   - ☐ $15,000 - $24,999
   - ☐ $25,000 - $34,999
   - ☐ $35,000 - $49,999
   - ☐ $50,000 - $74,999
   - ☐ $75,000 - $99,999
   - ☐ $100,000 or over

<u>THAT'S IT! YOU'RE DONE!</u>

<u>THANK YOU FOR YOUR PARTICIPATION!</u>

# DEMOGRAPHIC SURVEY

## RETURNING THE SURVEY AND FUTURE CONTACT

Please return this survey in the self-addressed envelope included in the original mailing. If you've misplaced that envelope, please send the survey to:

Peter Freeman
104 CEOAS Admin Building
Corvallis, OR 97330

Also, please feel free to contact us with any questions or comments:

**Peter Freeman** (student researcher)
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Tel: (203) 856-4136

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**Melissa Murphy** (liaison)
Email: melissa.m.murphy@state.or.us
Tel: (541) 867-7701 ext 229
Mail: 2040 SE Marine Science Dr., Newport, OR 97365

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