The Economic Value of Coastal Ecosystems in California

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I. INTRODUCTION TO MARINE ECOSYSTEM SERVICES

The status of marine ecosystems affects the well being of human societies. These ecosystems include but are not limited to estuaries, lagoons, reefs, and systems further offshore such as deep ocean vents. The coastal regions that connect terrestrial and marine ecosystems are of particular relevance to human societies. Marine, terrestrial, and coastal ecosystems all provide "ecosystem services" that are essential to human survival.

Ecosystem services[1] are defined as the benefits that nature provides to humans. By eating wild Pacific salmon or gazing out over Big Sur you are benefiting from ecosystem services. The marine environment of California provides ecosystem services all the time. Although we rarely pay for these services directly, we increasingly recognize that the provision of these services has economic value. In this report we discuss the dollar value of some ecosystem services and how economists calculate those values. The values we present were derived from a comprehensive review of the economics literature. The recognition of ecosystem services, and their valuation, is a new and emerging area in economics. Our review identified several significant gaps in the literature. In response to our findings we offer practical suggestions for furthering the documentation and valuation of California's coastal ecosystem services.

Ecosystem services provide economic benefits to society, although humans are not always aware of these benefits. The Millennium Ecosystem Assessment (MEA), generally regarded as standard guidance on this issue, is a comprehensive report on the status of ecosystems worldwide that was commissioned by United Nations Secretary General Kofi Annan in 2000. The MEA outlined four categories of ecosystem services:

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[1] For an in-depth explanation of ecosystem services, see "Ecosystems and Human Well-Being," available at http://www.millenniumassessment.org/documents/document.356.aspx.pdf accessed 3/2009
See also DeGroot, R.S., M.A. Wilson, and R.M.J. Boumans. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41:393–408.

• Provisioning (e.g., food, fresh water)

• Regulating (e.g., regulation of climate and erosion)

• Cultural (e.g., spiritual values, recreation), and

• Supporting (e.g., primary production, soil formation).

For instance, we benefit from provisioning services when we catch and eat animals that live and breed in estuaries. Estuaries provide regulating services because they absorb the force of storms in coastal areas and regulate changes in air and water temperature; air temperatures in coastal areas are less variable than inland temperatures.

I.1. Economic Importance of Coastal Resources

Oceans cover 71% of Earth's surface. As of 2007, 44% percent of the world's human population lives within 150 kilometers (93 miles) of the coast. In the United States, more than half the population lives in coastal counties. California ranks fifth among the states in terms of linear distance of tidal shoreline: 5515 km (3427 miles). In California, 27.2 million people (76% of the population as of 2007) live in estuarine regions[2]. Economic activity is intense in these areas, accounting for 80.7% (11.8 million) of all jobs and 85.8% of the state's Gross Domestic Product in 2007. This report focuses on the economic values of two types of ecosystems: beaches and estuaries.[3]

The California Ocean Protection Council seeks to incorporate economic values for coastal marine ecosystems into policy decisions. Because these decisions typically require

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[2] The United States Environmental Protection Agency defines an estuary as "a partially enclosed body of water along the coast where freshwater from rivers and streams meets and mixes with salt water from the ocean." http://www.epa.gov/nep/about1.htm, accessed 2/ 2009.

[3] Pendleton, L., editor. 2007. The economic and market value of coasts and estuaries: what's at stake? Restoring America's Estuaries, Washington, D.C.

economic analysis, and economic analysis of any kind of ecosystem service is rarely included in policy debates, it is important to approach the issue carefully.

Estuaries and beaches provide all four categories of ecosystem services recognized by the MEA. In addition, a relatively large body of economic and ecological research has been conducted on estuaries and beaches as compared with other marine systems such as the deep shelf, rocky intertidal zone, or deep-sea vents. The quantity of research on estuaries and beaches in part reflects their importance to human beings; estuaries and beaches have both commercial value and less-tangible human values. As such, these two ecosystem types provide good examples for explaining ecosystem services and their values.

II. INTRODUCTION TO NON-MARKET VALUATION OF ECOSYSTEMS

II.1. Valuation

A type of economic research called valuation[4] is often needed to measure the net economic consequences of human impacts to ecosystems. Basic valuation questions include

• What is the economic value (benefit) of *protecting* an ecosystem?

• What is economic value (loss) from *degrading* an ecosystem?

• What is the economic value (benefit) of *restoring* a degraded ecosystem?

Estimating these values requires information on the benefits and costs of various actions to society. A person can value an ecosystem for different reasons, and ecosystems provide multiple categories of economic benefits. From an economics perspective, it is important to ascertain the total economic value of an ecosystem. Total economic value includes market, non-market, use, and non-use values.

Economists define value in terms of utility. Utility is a metric of satisfaction that a person derives from consuming a good or service or taking part in an activity. Utility is typically measured by a person's willingness to pay or their willingness to accept. A person is willing to pay some amount in order to obtain a good or service, or they are willing to accept some kind of compensation if they can't obtain it.

[4] For more detail on the theory, background, and methods discussed in this report, see Champ, P.A, K.J. Boyle, and T.C. Brown, editors. 2003. A primer on nonmarket valuation. Kluwer Academic Publishers, Dordrecht, The Netherlands. Also see Freeman, A.M., III. 1993. The measurement of environmental and resource values. Resources for the Future, Washington, D.C.; and Bromley, D.W., editor. 1995. The handbook of environmental economics. Blackwell, Malden, Massachusetts.

II.2. Market and Non-Market Goods and Services

The value of a market good that is consumed by one buyer, such as an apple, is the amount a buyer is willing to pay for the good. If a good that is individually consumed is regularly bought and sold in a market, then the market price is a good indication of the value of that good to the people who actually buy it.

The value of a non-market good or service—one that is not regularly bought and sold—cannot be inferred from a market price. Economists typically classify ecosystem services as non-market. Using the concept of willingness to pay, economists define the value of an individually consumed non-market good as the amount that an individual consumer would be willing to pay to consume the good or use the service. These values are ascertained through empirical research.

II.3. Use and Non-Use Values

Market and non-market values are further categorized into use and non-use values. Ecosystems have value if their services are directly consumed by humans, such as through fishing, but ecosystems also have value if their services are not directly consumed. Use and non-use values can be broken down as follows:

- Direct use values
  - — Extractive values (e.g., commercial and subsistence fishing)
  - — Non-extractive values (e.g., catch-and-release sport fishing, wildlife viewing)
- Indirect use values (e.g., watching nature shows on television or reading a nature magazine)

• Non-use values (e.g., existence, or being happy to know that whales exist in the world even if you never see them; bequest, or knowing that your children will have the opportunity to live in a world with whales)

II.4. Importance and Application of Non-Market Values

Economists and ecologists are currently interested in ascertaining economic values for non-market resources. Non-market resources provide outputs or services that are not bought and sold, such as recreation, wilderness, and clean air. Estimating the value of non-market resources is important for several reasons. If non-market resources have value, these values can be included along with all other values considered in policy discussions or cost-benefit analyses. Using a monetary, or dollar, value is important because it allows societal preferences to be compared using an empirical and consistent measure, as opposed to a generalized qualitative statement or opinion. Monetary values are also relevant because a given person or business might take an action that improves or degrades the status of an ecosystem. An ecosystem has a monetary value if at least one individual or one business is willing to pay some positive amount to either

• compensate an individual or group that has suffered injury through the degradation of an ecosystem, or

• improve the condition of the resource.

To illustrate, assume that there are two possible conditions for an estuary, A and B. Condition A is relatively degraded. The functioning of the estuary is compromised by toxicants or other contaminants. An estuary in Condition B is much cleaner and more fully functioning.

Also assume a given person has some preferences about the estuary. If this person prefers Condition B to Condition A, then he or she might be willing to pay for a change from A to B (willingness to pay). He or she might also be willing to accept compensation for a change from B to A (willingness to accept).

If this person prefers Condition B, then the marginal value of the change to that person, or the amount of compensation, is the maximum payment that this person will make to improve the condition of the estuary or that will just compensate the person for the change from B to A. If this compensation is sufficient, economists say that the compensation would make this person indifferent between the two conditions.

There are two principal categories of methods for estimating the public values of ecosystems (or any other non-market good or service): stated preference and revealed preference. Stated preference methods use surveys (conducted by mail, in person, or online) that present hypothetical statements or intended choices to elicit responses about willingness to pay or accept.

Revealed preference methods infer values from statistical analyses of peoples' actual behavior. These methods can be applied to individuals or to groups. Researchers might target groups to capture a broader social or political perspective on a decision that impacts entire communities rather than individuals. Another method of estimating values for a given system, benefits transfer, takes values from existing studies (either revealed or stated preference) of one or more locations and transfers those values to a location that has not been valued but is similar to the original study location. Two other methods of estimating the value of ecosystem services, avoided cost and the productivity method, use different types of data. Avoided cost methods can be of particular interest to government agencies that would use public funds to repair damages to ecosystems, or built infrastructure that ecosystems protect, as a result of a development decision.

III. METHODS OF MEASURING WILLINGNESS TO PAY

We will focus on four methods of measuring willingness to pay: stated preference, revealed preference, avoided or replacement cost, and productivity. All four methods are commonly used in empirical studies. The principles behind these methods have gained wide acceptance among economists and policy makers.

III.1. Stated Preference Methods

Stated preference methods of measuring non-market values use surveys or interviews to ask people directly about their willingness to pay for some good or service. The surveys typically involve a choice about a hypothetical or proposed situation. A distinct advantage of stated preference methods is that they allow researchers and policy makers to target preferences for specific components of environmental changes, such as existence value. A disadvantage is that survey results can be affected by strategic responses, or responses that are designed to influence the outcome of the research, rather than by honest responses. Researchers have also found that some people are not willing to trade money for a loss in environmental quality.[5] Two types of stated preference methods are contingent valuation and choice experiments.

III.1.a. Contingent Valuation

Contingent valuation is a survey-based method[6] for determining the values people hold for a specific, proposed change in environmental quality. In a contingent valuation survey,

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[5] See Spash, C.L., 2002. Empirical signs of ethical concerns in economic valuation of the environment, in D.W. Bromley and J. Paavola, editors. *Economics, Ethics, and Environmental Policy: Contested Choices,* Oxford, Blackwell: 205-221.

[6] In addition to Champ et al. 2003, see Mitchell, R.C., and R.T. Carson. 1989. Using surveys to value public goods. The contingent valuation method. Resources for the Future, Washington, D.C.; and Arrow et al. 1993. Report of the NOAA panel on contingent valuation. http://www.darrp.noaa.gov/library/pdf/cvblue.pdf, accessed 11/2008.

respondents are presented with a hypothetical or proposed environmental scenario such as a specific change (or set of changes) in an environmental program or policy.

People's values are elicited through questions that address either willingness to pay or willingness to accept. Respondents are asked one of four questions:

1. What would they or their household be willing to pay for the change in environmental quality?
2. What would they or their household be willing to pay to avoid the change?
3. What would they or their household be willing to accept as compensation for the change?
4. What would they or their household be willing to accept to avoid the change?

The survey then proposes a payment method, such as a change in the amount of a water bill or a voluntary contribution into a fund. These payment methods are typically time-sensitive, so a well framed question will specify whether a single payment or a series of payments over time would be required.

For example, a contingent valuation survey could be based on a proposal to rehabilitate an estuary close to an urban area, such as San Francisco Bay. The particular valuation question could be, "How much would your household be willing to pay to increase the area of salt marsh in San Francisco Bay by 30%?" The answers to this question can be elicited in several ways.

Common elicitation formats for asking valuation questions include both open-ended and closed-ended formats. Open-ended formats do not provide a set of values from which to choose, leaving the respondent free to choose whatever value he or she feels is appropriate. Closed-ended formats supply a specific range of values from which to choose. A common closed-ended format is dichotomous choice, in which respondents must either accept or reject a given payment amount for the proposed change in environmental quality or access. The hypothetical referendum format is a dichotomous choice method, advocated by a Blue Ribbon National Oceanic and Atmospheric Administration (NOAA) panel (Arrow et al. 1993). In this format, respondents are given the opportunity to vote on a hypothetical referendum that would implement the described environmental change.

III.1.b. Choice Experiment

The choice experiment[7] is also a survey-based valuation method. Choice experiments and contingent valuation share the same underlying theory. Unlike contingent valuation, however, choice experiments partition a proposed change in the status of an environmental good or service into a set of specific attributes. Each attribute contributes to the overall utility that a person derives from a product. In the example of San Francisco Bay, the “product” that is being valued could be a rehabilitation strategy. Attributes that, if realized, would add value to a rehabilitation strategy might include a greater abundance of recreationally or commercially important fish species, improved air quality, and improved opportunities for bird watching (assuming a greater number of bird species nest and feed in the new marshes). Another attribute included in the survey is the cost for each outcome. Cost affects value and utility because a change in income is understood to produce a change in utility—the money paid for environmental benefits could be used to buy something else of value. The goal of a choice experiment is to assess how people simultaneously make trade-offs among the multiple attributes.

In a choice experiment survey, each respondent is presented a series of “choice tasks.” Each choice task presents two or more options that are carefully designed to vary with respect to

[7] For more detail on the choice experiment, see Hanley, N., S. Mourato, and R.E. Wright. 2001. Choice modeling approaches: a superior alternative for environmental valuation? Journal of Economic Surveys 15:435–462.

each of the attributes. One rehabilitation initiative, for example, could lead to a 20% increase in the extent of salt marsh but not affect bird abundance, at a cost of $15 per household. Another initiative could result in a 50% increase in marsh area and increased abundance of birds but cost each household $40. People with different beliefs and preferences will tend to pick different options, allowing economists to calculate and statistically differentiate willingness to pay for each attribute.

Choice experiments have several advantages relative to contingent valuation. Choice experiments provide more-detailed information about people's preferences over a range of outcomes, are less prone to biases caused by respondents answering questions strategically, and yield a greater amount of information than a contingent valuation survey for the same cost. A possible disadvantage of a choice experiment relative to contingent valuation is that because choice-experiment surveys are more detailed, it can be more difficult for people to respond or they may be less likely to respond.

III.1.c. Construction of Stated Preference Surveys

Both contingent-valuation surveys and choice experiments provide detailed information on a given ecosystem and on the proposed method of changing the status of that ecosystem. A valuation survey addressing rehabilitation of San Francisco Bay would provide information on the current state of the Bay and a projected improved state, as well as on how the improvements would be achieved. The survey also would include questions about the respondent's perceptions of current environmental quality and how he or she feels about the proposed project. Valuation surveys typically end with questions about demographic attributes, such as income and race. Although some respondents find demographic questions intrusive, the questions are critical for several reasons. Most importantly, demographic questions ensure that the group of respondents is statistically similar to the entire group being surveyed. By using statistical methods, it is possible to ascertain whether the group that responded to the survey is representative of the group whose attitudes the researcher is investigating.

Assume the survey about increasing the area of salt marsh in San Francisco Bay was targeted at residents of the San Francisco Bay area[8] (Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma counties). It would be expensive (and statistically unnecessary) to contact all 6.89 million people living in the area. Instead, a researcher could draw robust inferences by compiling survey responses from a group that was representative of all San Francisco Bay area residents. Information on the composition of the region's population is available from the state of California or the U.S. Census Bureau. A researcher can use that information to determine how the survey should be distributed and to evaluate whether the group of respondents sufficiently resembles the entire group. For example, in 2007, the estimated median household income in the nine San Francisco Bay area counties was $72,630, and approximately 51% of the area's residents described themselves as white and non-Hispanic. If the median household income reported by survey respondents was $150,000, and 85% of the respondents described themselves as white and non-Hispanic, then the survey data would not be representative of values across the region.

Demographic questions also allow for comparing responses among different subsets of survey respondents. It is possible to compare responses between homeowners and renters, for example, or between high-income and low-income households within a given racial group. It also can be important for researchers and policy makers to understand the relationships between certain demographic attributes (e.g., education) and willingness to pay. Demographic questions

[8] All data for the San Francisco Bay area from http://www.bayareacensus.ca.gov/bayarea.htm, accessed 2/2009.

are common in valuation research, and would be included in any well-designed survey of willingness to pay. Demographic information is also crucial given that one of the major critiques of willingness to pay surveys is that making decisions based on the survey results biases the preferences of those who are able to pay more.[9] Thus, demographic information can assist public decision-makers in compensating for any economic disparities among respondents.

III.2. Revealed Preference Methods

Revealed preference methods of measuring non-market values are based upon inferring willingness to pay from people's actual payments for other goods or services that are associated with their use of the non-market resource. The primary advantage of revealed preference methods is that they are based on actual behavior, with existing prices. The primary disadvantage of revealed preference methods is that they can only be used to measure use value; they cannot be used to measure other kinds of non-market value such as option value or existence value.

III.2.a. Hedonic Pricing

Hedonic pricing infers willingness to pay for non-market resources by observing how much people are willing to pay for other resources that convey the right or ability to use a non-market resource. A typical example of hedonic valuation involves housing prices. The underlying theory of hedonic pricing is that, all else being equal, there is a consistent relationship between the value of homes and their proximity to some environmental good. For example, houses with a bay view (closer to the bay) would be worth more than houses without a bay view (farther away). Of course, a researcher must control for home types. It would be unreasonable to

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[9] Munda, G. 1996. Cost-benefit analysis in integrated environmental assessment: some methodological issues. Ecological Economics 19:157-168.

compare a 5000 square foot house with a two-car garage that lies two miles from the San Francisco Bay to a 200 square foot unheated cabin adjacent to the Marin Headlands.

III.2.b. Travel Cost

The travel cost method measures economic values associated with recreational sites, which can include ecosystems. Travel cost estimates willingness to pay using the costs of travel to access a resource, such as expenditures for fuel or airline tickets and the opportunity cost of travel time. Because these costs of travel vary among site users, it is possible to construct a demand curve for the resource (or ecosystem service) using these data. The "opportunity cost" of travel time is generally defined as the value of the next-best use of that time. If travel for vacation is the best use of a person's time, the next best use of their time is generally paid employment. In other words, instead of spending their time at work, a person is choosing to spend their time traveling for vacation. Because people are not paid to travel for vacation, economists use an average wage value to calculate the amount of money people are giving up in order to travel and thus what value they place on their time.

III.3. Other Non-Market Valuation Methods

III.3.a. Avoided Cost or Replacement Cost

The avoided cost or replacement cost[10] method estimates the economic value of a natural system by calculating the cost of replacing the system with a human-made or purchased equivalent. A classic example of replacement cost involves estimating the cost of replacing the water filtration services provided by undeveloped watersheds with a water-filtration plant. An

[10] For examples of replacement cost estimates of wetlands values, see Boyer, T., and S. Polasky. 2004. Valuing urban wetlands: a review of nonmarket valuation studies. Wetlands 24:744–755.

example of avoided cost would be the amount of damage to property and lives that would not have resulted from a hurricane if large wetlands were preserved or restored to absorb storm surges.[11]

Replacement cost is approximate, as no human-built system can provide all of the ecosystem services of a natural system. "[R]eplacement cost typically focuses on one service provided by a wetland (e.g., wastewater treatment) rather than the complete range of values associated with a wetland and should not be confused with the total value of the wetland (Boyer and Polasky 2004:750)." Nevertheless, estimates of replacement cost can be useful. Table 2 indicates ecosystem services that could be valued by this approach.

III.3.b. Productivity Method

The productivity method, also called the net factor income or derived value method, is used to estimate the economic value of ecosystem products or services that contribute to the production of commercially marketed goods. The productivity method is applied in situations where the outputs of an ecosystem are used as an input to produce a market good or service. For example, the productivity of fish stocks is affected by the status of their habitat, so the economic value of improving habitat quality for a given species of fish can be measured using increased fishing revenues.[12]

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[11] Costanza, R., O. Perez-Maqueo, M. Luisa Martinez, P. Sutton, S. Anderson, and K. Mulder 2008. The value of coastal wetlands for hurricane protection. Ambio 37:241-248.

[12] See http://noep.mbari.org/nonmarket/methodologies.asp, accessed 9/2008.

IV. APPLICATION OF NON-MARKET VALUATION TO DECISION MAKING IN THE COASTAL ZONE

Understanding the total economic value of ecosystems is useful for informed decision making in the coastal zone. The regulatory framework governing decisions by federal, state, and local agencies generally requires broad consideration of impacts of those decisions on the market, non-market, use, and non-use values of marine ecosystems. For example, guidelines for analyzing federal infrastructure investments (bridges, roads, pipelines, and port facilities) in the United States contain the following direction: "all types of benefits and costs, both market and non-market, should be considered. To the extent that environmental and other non-market benefits and costs can be quantified, they shall be given the same weight as quantifiable market benefits and costs."[13]

Guidance for federal agencies is equally explicit. For example, the Army Corps of Engineers is required to evaluate all water resource development projects in the coastal zone according to its National Economic Development Procedures manual, which was derived from regulations promulgated by the Water Resources Council in 1983. In the National Economic Development framework, "resource use is broadly defined to include all aspects of the economic value of the resource."[14] As such, Corps regulations and guidance manuals explicitly call for addressing non-market benefits and costs of water resources development, such as the benefits associated with enhanced recreational use or externalities from water pollution.[15] An externality (sometimes called a spillover) is a cost or benefit that is generated by some activity, but is not

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[13] Principles for federal infrastructure investments, Executive Order 12893 at Section 2(a)1.

[14] Water Resources Council. 1983. Economic and environmental principles and guidelines for water and related land resources implementation studies, Section VII: 1.7.2(f).

[15] The Corps has a mandate to incorporate externalized costs into its National Economic Development analysis: "[t]he NED principle requires that externalities be accounted for in order to assure efficient allocation of resources." Institute for Water Resources. 1991. National Economic Development Procedures Manual—Overview Manual for Conducting National Economic Development Analysis. U.S. Army Corps of Engineers, Water Resources Support Center, Institute for Water Resources, Fort Belvoir, Virginia, page 21.

incorporated into the activity's market value. For example, water pollution from agriculture might adversely affect downstream fishing communities. These communities pay a cost for the decreased water quality—fish die and become scarcer, which decreases incomes from fishing—but agriculturalists that generate the pollution do not pay for it and the cost of the pollution is not reflected in the retail price of food. That cost is therefore externalized to the fishers, and is described as an externality. Externalities can be positive or negative.

At the state level, statutes governing economic analysis of policies, plans, and projects that affect environmental resources often direct agencies to consider both market and non-market impacts and to discuss the link between changes in environmental conditions and economic uses. For example, regulations implementing California's Environmental Quality Act (CEQA) state that if a proposed project might change the economic or social values associated with an environmental resource, the project can require an environmental impact report: "[e]conomic or social effects of a project may be used to determine the significance of physical changes . . . " 14 C.C.R. 3 § 15131. Thus, if a policy, program, or project causes the loss of a relatively small area of an estuary but the economic value of that loss is substantial, CEQA may require an environmental impact report. Similarly, California's Water Quality Control Board is required to regulate activities that affect whether the waters of the state can "attain the highest water quality which is reasonable, considering all demands being made and to be made on those waters and the total values involved, beneficial and detrimental, economic and social, tangible and intangible" (CWC[16] § 13000). Thus, the current regulatory framework requires consideration of the impacts of any policies, programs, or projects affecting coastal ecosystems on the total economic value of those ecosystems. Nonetheless, and because valuation of ecosystem services is still a relatively new discipline, there are few examples where ecosystem services or other non-market values

[16] California Water Code

have informed policy decisions in California or elsewhere, and there has been little enforcement of regulatory provisions regarding economic valuation. In California, however, the issue is gaining traction. The state's Ocean Protection Council is investigating ways to incorporate non-market values into legislative proposals, budget change proposals, and regulatory and permitting processes. Specific policy settings ripe for consideration of ecosystem services and other non-market values include decisions about establishment of marine protected areas, offshore aquaculture, coastal zone management, wetlands, fishing techniques, eradication of invasive species, and restoration of wild salmon populations.

V. RESULTS FROM VALUATION STUDIES ON ESTUARIES AND BEACHES

We searched the economic literature on ecosystem service valuation to determine what values people hold on a per-acre basis for estuarine and beach ecosystems worldwide. We found that such information is limited. Economic valuation of ecosystem services is a relatively recent phenomenon. Non-market environmental valuation research does not always address ecosystem services explicitly. A recent book examining the economic value of estuaries found that out of 300 sources reviewed, “about 230 citations (>77%) were rejected because they . . . did not explicitly address the economic valuation of coastal ecosystem goods and services” (Pendleton 2007:29). Another issue we identified is that even when ecosystem services were directly addressed in surveys, the services often were not addressed in a spatially explicit manner. Although it is possible to estimate values for almost all types of ecosystem services on a spatially explicit basis (values per hectare or acre of ecosystem), a majority of studies have not done so. Previous studies have focused on specific proposed changes either to a known area, such as beaches in southern California, or to an ecosystem that is not spatially defined in the survey.

Table 1. Worldwide ecosystem service values in 2008 US$ / acre. Notes in Appendix 2. Service categories from the Millennium Ecosystem Assessment.

	Ecosystem Type	
Service Category	Estuary	Beach
PROVISIONING		
food		
--capture fisheries	55 – 1,831	-
--aquaculture	-	-
--wild plant and animal products	26 – 868	-
fiber	-	-
genetic resources	-	-
biochemicals, natural medicines, pharmaceuticals	-	-
ornamental resources	-	-
human habitation	-	-
human navigation	-	-
energy (for human use)	-	-
REGULATING		Note 2
air quality regulation	-	-
climate regulation	-	-
erosion regulation	-	31,131
water purification, waste treatment	2,500 (Note 5)	-
disease regulation	-	-
pest regulation	113	-
pollination (and seed dispersal)	-	-
natural hazard regulation	332 – 16,341	-
freshwater storage and retention	-	-
gas regulation	-	-
CULTURAL		-
cultural diversity	-	-
spiritual and religious values	-	-
knowledge systems	-	-
educational values	-	-
inspiration	-	-
aesthetic values	-	-
social relations	-	-
sense of place	-	-
cultural heritage values	42	27
recreation and ecotourism	46 – 6,254	16,946 (Note 2)
SUPPORTING		-
habitat and refugia*	192	-
photosynthesis	-	-
primary production	1,351 – 69,671	-
nutrient cycling	-	-
water cycling	-	-
BUNDLED ATTRIBUTES**	50,000 – 80,000 (Note 5)	36,000 – 83,000 (Note 2)

* Habitat and refugia is not a category recognized by the MEA. However, Costanza et al. (1997) presented values from this category, and habitat values of estuaries are often discussed in the valuation literature.
** “Bundled attributes” refers to cases in which people were asked to value estuarine ecosystem services generally, rather than by category.

Economic values vary by attitudes, experience, and income. Table 1 catalogues economic values for ecosystem services provided by estuaries and beaches. These values are derived from research conducted around the world. A considerable range of values for the same ecosystem service is not unusual. The variation does not mean that the research methods were flawed. For example, prices for gasoline differ across the United States, and prices for identical prescription drugs vary in the United States, Canada, and Mexico. Rather, this variability argues for the necessity of original, site-specific valuation studies. It also argues for caution in making decisions based on existing but incomplete data. For example, using values in the tables in this report to “rank” the importance of one ecosystem or service to another would not be credible. In addition, the total value per acre of a beach used by many people will be greater than the value per acre of a similar beach used by fewer people.

VI. POTENTIAL NEXT STEPS

If the state of California wishes to incorporate non-market values of marine and coastal ecosystems into decision making in a comprehensive manner, it will be necessary both to map ecosystems and the services provided by them and to conduct original economic research on the value of those services. A possible first step is to prioritize which ecosystems and ecosystem services are most relevant to current management and policy initiatives in the state. Prioritization of ecosystems and ecosystem services will increase the efficiency of credible collection and analysis of data on non-market values.

Spatially explicit data on land cover—the geographic configuration of different ecosystems—exist for most of California at relatively high resolution. Contiguous areas of a given land-cover type or ecosystem type often can be delineated into “patches” or polygons. In some cases, it is possible to estimate the status of a given service provided by that patch or polygon. For example, one might estimate the status of some fishery species (a provisioning service) on the basis of data on the location and density of eelgrass, which provides habitat for many species of commercial and recreational importance. The status of water purification and waste treatment, a regulating service provided by estuaries, might be estimated on the basis of areal coverage of marshes as well as percentage impervious surfaces in catchments adjacent to the estuary. The Albemarle / Pamlico National Estuary Program has used spatially explicit data on submersed aquatic vegetation to map the location of several supporting services provided by estuaries, including nitrogen cycling and net primary production. Once services are mapped and their status is estimated, it is possible to conduct valuation research related to current status or potential changes in status.

It is preferable to map and value ecosystem services at the level of ecological units rather than political units. For example, services associated with aquatic systems might be mapped and valued at the level of watersheds. Watersheds can be delineated at relatively high resolution with Hydrologic Unit Codes (HUCs), a standardized system used by the Environmental Protection Agency and U.S. Geological Survey. Proposed projects often take place within a legislative or municipal unit that includes several watersheds, such as a county, and economists and policy analysts typically work within boundaries established by governance rather than by ecological processes. Nevertheless, watershed-level data estimates of the status and value of ecosystem services are more robust than estimates at the level of, say, 10 km x 10 km grids. If necessary, values for multiple watersheds within a county or a similar political unit can be aggregated.

As described above, different methods of economic valuation are applicable to different ecosystem services. For example, whereas replacement cost can be used to value some types of services, it does not capture all of the values consistently provided by an ecosystem. Because cultural services typically are non-use values, they must be quantified using stated preference methods such as contingent valuation or choice experiments. By conducting a set of original, place-based valuation studies for different prioritized services in different ecosystems in California, we can dramatically improve the scientific base of information for decisions affecting the state's coastal resources.

Table 2. Economic values of ecosystem services in California categorized by ecosystem type and amenability to valuation by avoidance cost or replacement cost methods. All values converted to 2008 US$. Notes in Appendix 1.

Service Category	marsh	beach	mud flat	lagoon and salt pond	estuary	rocky intertidal	kelp	rocky reef	shell reef	seagrass	inner shelf	outer shelf, edge, slope	seamount and mid-ocean ridge	inner shelf
PROVISIONING	-	-	-	-		-	-			-	-	-	-	-
food						-	-	Note 7	Note 7	-	40 – 55	9	-	40 – 55
--capture fisheries	-		-	-	55 – 1,831	-	-	-	-	-	-	-	-	-
--aquaculture	-		-	-		-	-	-	-	-	-	-	-	-
--wild plant and animal products	-		-	-	26 – 868	-	-	-	-	-	-	-	-	-
genetic resources	-		-	-		-	-	-	-	-	-	-	-	-
biochemicals, natural medicines, pharmaceuticals	-		-	-	-	-	-	-	-	-	-	-	-	-
ornamental resources	-		-	-	-	-	-	-	-	-	-	-	-	-
human habitation	-		-	-	-	-	-	-	-	-	-	-	-	-
human navigation	-		-	-	-	-	-	-	-	-	-	-	-	-
energy (for human use)	-		-	-	-	-	-	-	-	-	-	-	-	-

Service Category	marsh	beach	mud flat	lagoon and salt pond	estuary	rocky intertidal	kelp	rocky reef	shell reef	seagrass	inner shelf	outer shelf, edge, slope	seamount and mid-ocean ridge	inner shelf
REGULATING					-	-	-	-	-	-	-	-	-	-
air quality regulation	-		-	-	-	-	-	-	-	-	-	-	-	-
climate regulation	Note 1		-	-		-	-	-	-	-	-	-	-	-
erosion regulation	-	31,131	-	-	-	-	-	-	-	-	-	-	-	-
water purification, waste treatment	-		-	Note 4	2,500 (Note 5)	-	-	Note 7	Note 7	-	Note 9	-	-	Note 9
disease regulation	-		-	-	-	-	-		-	-	Note 9	-	-	Note 9
pest regulation	-		-	-	113	-	-	-	-	-	-	-	-	-
pollination (and seed dispersal)	-		-	-	-	-	-	-	-	-	-	-	-	-
natural hazard regulation	-		-	-	332 – 16,341	-	-	Note 7	Note 7	-	52	-	-	52
freshwater storage and retention	-		-	-	-	-	-	-	-	-	-	-	-	-
gas regulation	-		-	-	4,145 – 16,341	-	-	-	-	-	-	22	-	-

Service Category	marsh	beach	mud flat	lagoon and salt pond	estuary	rocky intertidal	kelp	rocky reef	shell reef	seagrass	inner shelf	outer shelf, edge, slope	seamount and mid-ocean ridge	inner shelf
CULTURAL					-	-	-	-	-	-	41 – 45	45	-	41 – 45
cultural diversity	-		-	-	-	-	-	-	-	-	-	-	-	-
spiritual and religious values	-		-	-		-	-	-	-	-	-	-	-	-
knowledge systems	-		-	-	-	-	-	-	-	-	-	-	-	-
educational values	-		-	-	-	-	-	-	-	-	-	-	-	-
inspiration	-		-	-	-	-	-	-	-	-	-	-	-	-
aesthetic values	-		-	-	-	-	-	-	-	-	-	-	-	-
social relations	-		-	-	-	-	-	-	-	-	-	-	-	-
sense of place	-		-	-	-	-	-	-	-	-	-	-	-	-
cultural heritage values	-	27	-	-	42	-	-	Note 7	Note 7	-	-	-	-	-
recreation and ecotourism	-	16,945 (Note 2)	-	Note 4	46 – 6,254	-	-	Note 7	Note 7	-	120	Note 10	-	120
SUPPORTING					-	-	-			-	-	-	-	-
photosynthesis	-		-	-	46 – 6,254	-	-	-	-	-	-	-	-	-
primary production	-		-	-	1,351 – 69,671	-	-	-	-	-	-	-	-	-
nutrient cycling	-		-	-	-	-	-	-	-	11,188 (Note 8)	2,081 – 5,350	69	-	2,081 – 5,350
water cycling	-		-	-	13,854 – 69,671	-	-	-	-	-	-	-	-	-
BUNDLED ATTRIBUTES**	(Note 1)	31,500 – 72,900 (Note 2)	Note 3	Note 4	421 – 817 (Note 5)	Note 6								

** "Bundled attributes" refers to cases in which people were asked to value estuarine ecosystem services generally, rather than by category.

VII. APPENDICES

VII.1. Appendix 1: Recommendations for categorizing valuation by ecosystem service type

Based in part on a description of information needs from staff of the California Ocean Protection Council, we reviewed the different types of ecosystem services by ecosystem types to ascertain whether it might be possible to streamline the process of valuation. By identifying whether particular valuation methods would be most appropriate for valuing particular types of services, it might be possible to determine which ecosystem services might be valued relatively rapidly or cheaply. It is important to note that ease of valuation does not correspond with importance of a given service. In other words, if one type of service is easier to value than another, it does not mean that the former service is more important to human well-being or even to any proposed project, or that other types of services requiring more detailed or time-consuming methods of valuation should be ignored.

We reviewed the Millennium Ecosystem Assessment's table of ecosystem service types against a matrix of dominant marine ecosystem types in California. We determined that values for some types of services, in certain ecosystems, can be approximated by applying the avoided cost or replacement cost method (Table 2). As outlined in the text, the avoided cost method calculates the economic value of benefits that are provided by an ecosystem and would not exist if the character of the ecosystem was fundamentally different. As such, avoided costs can be calculated by estimating the cost of replacing the existing ecosystem with either a built substitute or a restored system.

Services highlighted in light yellow are those for which we believe credible values can be estimated by the avoided cost or replacement cost method, given the caveats in the text of this report and in the literature. Services highlighted in light red are those we have deemed irreplaceable. To estimate the economic value of these services, it is imperative to conduct either original, site-specific and service-specific research or high-quality benefits transfer. All other services are beyond the scope of our discussion.

VII.2. Appendix 2: Notes to Tables 1 and 2.

All values reported in Tables 1 and 2 are service flows in U.S. dollars per acre per year. These notes report many additional values with different units, such as dollars per household per year. All dollar values have been adjusted to year 2008 U.S. dollars using the Consumer Price Index for urban consumers (CPI-U). Foreign currencies were first converted to U.S. dollars using the prevailing exchange rate for the year in which data were collected.[17] Willingness to accept refers to acceptance of compensation for loss of the ecosystem service. Willingness to pay refers to payments made for the continuation of or an increased level of provision of the ecosystem service.

1. Marshes

For **bundled services**, a low value of $2094 per acre one-time is from De Maio Sukic (2001), who measured the willingness of Bay of Fundy property owners to sell property to a conservation program (willingness to accept). A high value ($263,000 per acre one-time) comes from a contingent valuation survey that determined willingness to pay for preservation or restoration of salt marsh in Rhode Island (Bauer et al. 2004). Bauer et al. determined that each household in the state had a mean one-time willingness to pay of $0.64 per acre and multiplied by 408,000 households in Rhode Island to produce the aggregate value.

De Maio Sukic (2001) also derived a value for **climate regulation services**. They expressed results in terms of metric tons of carbon dioxide-equivalent sequestered. If one imagines the Bay of Fundy salt marsh is purchased for the sole purpose of retaining its sequestration services, the cost ranges from $14 to $17 per metric ton of carbon dioxide sequestered.

[17] Currency conversions from data at http://www.oanda.com/convert/fxhistory

2. Beaches

Beach value per acre. Costanza et al. (2006) generated values per acre, but only after extensive GIS analyses based on other studies and on their hedonic analysis of real estate values. Their values of $31,131 per acre per year for disturbance control, $16,946 per acre for recreation and tourism, and $27 per acre per year for cultural heritage are benefits transferred from other studies.

In a separate hedonic pricing study of how proximity to beaches was reflected in real estate values, Costanza et al. (2006) found that beaches yield a flow of bundled services of between $36,000 per acre per year and $83,000 per acre per year.

Beach value per user-day. Most estimates for beaches are for the value of a user-day at the beach. Bin et al. (2004) generated estimates ranging from $13 to $94 per user-day for North Carolina beaches. Adamson-Badilla et al. (1997) calculated a range of $18 to $81 per visitor-day for beaches in Costa Rica. In general, there seems to be agreement on a range of values between $30 and $50 per beach user-day.

Lew and Larson (2005) estimated a range of $28 to $42 per beach user-day among San Diego County residents using San Diego County beaches. Like the above estimates, these values are based on the alternative of not going to the beach at all. Lew and Larson also found that people would suffer a loss of only about $1–2 per user-day as a result of not being able to visit a particular beach on a particular day, but assuming that other beaches remained available. The dramatic difference between these two values ($28 - 42 vs. $1-2) illustrates the potential difference between overall/average valuations ("beaches in general") and the incremental value of a small change in services ("one beach closed for one day").

Other beach values. Dornbusch et al. (1987) derived a total value of between $1.5 billion and 3.0 billion per year for beach-related recreation for all of California. Edwards et al. (1991) found beach values of $1229 per person per year for people living within 12 miles of a beach in Rhode Island. Lindsay et al. (1992) estimated that people were willing to pay $56 per person for one-time beach protection. Silberman et al. (1992) focused on existence values and found a one-time willingness to pay value of $19 per non-visitor. This was elicited through a survey of non-users as the one-time willingness to pay for the hypothetical restoration of an unspecified set of New Jersey beaches to a width of between 150 and 200 feet.

3. Mudflats

Bundled services. Hammit et al. (2001) estimated the annual per household value of preserving the Kuantu wetland in Taiwan using contingent valuation. They found a mean willingness to pay of $31 per household per year using open-ended questions and $96 per household per year using dichotomous choice questions. Chuenpagdee (1998) found that a sample of Thai people were willing to accept between $47 and $61 per person one-time as compensation for hypothetical resource damage to mudflats in Ban Don Bay.

4. Lagoons and Salt Ponds

Water purification. Anderson (1986) found that the citizens of one Rhode Island community had a willingness to pay of $6.7 million in aggregate net present value to keep the water quality of local salt ponds sufficiently high for swimming.

Recreation. Alberini and Zanatta (2005) measured an aggregate welfare improvement of $3.9 million related to maintaining recreational fisheries through pollution control. The average consumer surplus from recreational fishing in the Lagoon of Venice was measured at $2607 per household per year (Zanatta et al. 2005). Anderson (1986) found that the citizens of one Rhode Island community had a willingness to pay of $13.4 million in aggregate net present value to protect recreational uses of salt ponds. This value may subsume the above value for preserving conditions safe for swimming.

Bundled services. Italian households were willing to pay between $41 and $63 per household one-time for improvements to the Lagoon of Venice (Alberini et al. 2004). Using contingent valuation methods, Wey (1990) found that visitors and residents of Block Island, Rhode Island were willing to pay between $45 and $69 per person to improve water quality in Great Salt Pond. It was not clear whether these numbers represented one-time or recurring values.

5. Estuaries

Capture fisheries. Costanza et al. (1989) estimated $55 per acre per year and Farber et al. (1987) estimated $81 per acre per year as the derived value of wetlands in support of commercial harvests of shrimp, menhaden, oyster, and crab in coastal Louisiana.

Trapping. Costanza et al. (1989) estimated a value of $26 per acre per year based on the market value of fur pelts.

Estimated values for both commercial fishing and trapping values should be considered high because they reflect the "ex-vessel" value of fish and the market value of fur pelts, rather than the value added by the ecosystem. The ex-vessel value of fish embodies the fisher's effort and the services of his or her fishing equipment.

Natural hazard regulation. The value of $332 per acre per year was estimated by Costanza et al. (1989) based on avoidable hurricane damages in Louisiana.

Recreation and tourism. A lower value of $8 per acre per year comes from Costanza et al. (1989), who conducted a survey of residents in coastal Louisiana. The high value is for New Jersey. The New Jersey study estimated a value of $224 per household per year. Hosking (2004) found a willingness to pay of $51 per household per year for additional recreational use from increased water flows through an estuary in South Africa. Kaoru et al. (1995) generated values ranging from $22 to $38 per party per trip for recreational fishing in North Carolina's Albemarle and Pamlico Sounds. Whittington et al. (1994) used contingent valuation methods to derive a value of $200 per respondent per year for improvements to Galveston Bay.

Supporting services. For gross primary production, Costanza et al. (1989) developed estimates ranging from $1351–1978 per acre per year for Louisiana. They converted gross primary production to dollars based on the energy content of biomass produced.

Total values. The low total value of $421 per acre per year is for Louisiana from Costanza et al. (1989). The low total value is the sum of components for commercial fishing, trapping, hazard regulation, and recreation. The high total value of $817 per acre per year is the sum of water supply, habitat, and recreation values for New Jersey (Costanza et al. 2006).

Kirshner and Moore (1989) reported increases in property values ranging from nine percent to 20 percent as proximity to San Francisco Bay increased. Milon et al. (1999, 2005) found a willingness to pay of between $78 and $93 per household per year for "full restoration" of the Florida Everglades (quotations in original).

6. Rocky Intertidal

Bundled services. Hall et al. (2002) found a mean of $7 per family per visit to prevent reductions in the status of the rocky intertidal zone in southern California. The number of family-visits was unknown or not provided, so no aggregate value could be calculated.

7. Rocky Reefs and Shell Reefs

We could not find any studies of values associated with rocky reefs or shell reefs. The following numbers are all for coral reefs. Costanza et al. (1997) estimated the following service values for coral reefs:

Ecosystem service	2008$ per acre per year
Food production	130
Disturbance regulation	1619
Waste treatment	34
Recreation	1771
Cultural	1

Allport and Epperson (2003) found that businesses dependent on ecotourism to sites with coral reefs as prominent features were willing to pay between zero and $554 per business to maintain the quality of these sites on four Windward Islands in the Caribbean.

Seenprachwong (2001) found that international visitors were receiving a value of $1870 per visit to coral reefs at Phi Phi Islands in the Andaman Sea in Thailand. Domestic Thai visitors were receiving a value of $106 per visit.

8. Seagrass

Nutrient cycling. The value of $11,188 is for “seagrass / algae beds” from Costanza et al. (1997).

9. Inner Shelf

The ranges of values reported in the table are from the use of the values for both “coastal” and “shelf” ecosystem types from Costanza et al. (1997).

Several studies estimated values for **improved water quality** in coastal waters (Georgiou et al. 2000, Kosenius 2004, Le Goffe 1995). These estimates ranged from $33 per visitor per year to $79 per household per year. The exact nature of the water quality improvements was not discernable.

Recreation. Rowe et al. (1985) estimated several values associated with sport fishing off the coasts of California, Oregon, and Washington. For California, they estimated that anglers were willing to pay zero to $20 per salmon per trip for increased recreational salmon catch.

10. Outer Shelves, Edges, and Slopes

The values reported in the table are for the “open ocean” ecosystem type from Costanza et al. (1997).

Recreation. Loomis et al. (1994) used contingent valuation to measure the value placed on increased abundance of gray whales (Eschrichtius robustus) in California waters. They found that willingness to pay for a 50% increase in abundance of whales was $36 per year for visitors and $43 per year for residents.

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