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Application of non-market valuation to California's coastal policy decisions

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A B S T R A C T

Regulatory agencies in the United States do not generally consider economic values of ecosystem services in their policy decisions. We report the results of a collaborative effort by a team of economists, conservation biologists, and staff members of the California Ocean Protection Council to provide spatially explicit and policy-relevant values for ecosystem services generated in coastal regions in California. We developed a matrix in which the rows are types of ecosystem services and the columns are types of marine ecosystems along the California coast. Where possible, we populated this matrix with ecosystem service values per unit of area drawn from the economics literature. We then evaluated whether the values for given services, in given ecosystems, could be reasonably approximated by applying the replacement cost or the avoided cost method. Reported values of coastal ecosystems varied widely, and much of the valuation research did not address specific ecosystem services. Even when ecosystem services were explicitly addressed, the services often were not described or valued in a spatially explicit manner. These results suggest that rigorous application of non-market values to policy decisions requires original valuation studies for specific services in specific ecosystems. Where original, place-based valuation studies are not possible, valuation by replacement or avoided cost methods is feasible for some ecosystem services.

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1. Introduction

Better understanding of the total economic value of ecosystems might improve policy and management decisions affecting those ecosystems [1,2]. Total economic value includes the values of both market and non-market goods and services. The economic value of a market good or service consumed by one buyer, such as an apple, is the amount the buyer is willing to pay for it. The market price provides information about these values, although such values vary among individuals. The economic value of a non-market good or service, such as clean air or a scenic view, is similarly defined as the amount that a consumer would be willing to pay for the good or service if payment were possible. However, because there are often no market prices to reveal these values, values must be ascertained through empirical research with

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methods such as contingent valuation and the travel cost method [3,4]. This absence of prices can hinder comparison of use values of these areas. Whereas revenues from a housing development built on a drained wetland are relatively straightforward to calculate, estimating the value of the benefits from the original wetlands requires nonmarket valuation.

Recognizing that more systematic use of non-market values might increase the rigor and defensibility of coastal policy decisions, two members of the California Ocean Protection Council (OPC) worked directly with a team of economists and conservation biologists to develop guidelines for OPC to apply when valuing ecosystem services (the benefits that ecosystems provide to humans [5]) generated in coastal regions in California. This collaborative group is referenced in the first person plural. Through a series of intensive workshops, we identified gaps between the decision-makers' needs and what researchers felt could be could be inferred from the best available science, and proposed ways to bridge those gaps. The results and insights we obtained are potentially transferable to coastal, marine, and terrestrial systems in other geographic regions.

1.1. Social, economic, and ecological context

California epitomizes the tendency of human populations to live in coastal areas: in 2007, 76% of the state's population (27.2 million people) lived in estuarine regions [6]. These regions were associated with 81% of California's jobs and 86% of its economic output [6]. Accordingly, coastal areas are often the focus of policy decisions by public agencies. Whereas these decisions often require economic analysis, quantitative economic values for the affected ecosystem services are rarely included in policy debates. Despite this lack of quantification, the ecosystem services generated by two types of coastal systems, estuaries and beaches, are particularly important to state decision-makers. These systems provide substantial amounts of provisioning, regulating, cultural, and supporting services as defined by the Millennium Ecosystem Assessment [5]. Therefore, it is likely that these systems have substantial economic value.

Regulations implementing the California Environmental Quality Act (CEQA) state that "[*e*]conomic or social effects of a project may be used to determine the significance of physical changes" [7]. Thus, if a project would alter a relatively small proportion of an estuary but the economic value of that change 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"[8].

Although our work focused on California, it may inform national-level decisions in the United States and other countries. In the United States, regulations affecting decisions of federal agencies about coastal ecosystems generally require consideration of the effects of decisions on the total economic value of those ecosystems. For example, guidelines for analyzing federal infrastructure investments (bridges, roads, pipelines, and ports) contain the following direction: "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" [9]. Similarly, the Army Corps of Engineers' regulations and guidance, such as its National Economic Development Procedures Manual [10], explicitly call for addressing non-market benefits and costs of water resources development, such as the benefits associated with enhanced recreational use or the costs imposed by water pollution [11].

1.2. Coastal policy decisions in California

The California OPC was created under the California Ocean Protection Act of 2004. The OPC's mission is to ensure that "California maintains healthy, resilient, and productive ocean and coastal ecosystems for the benefit of current and future generations." Among the OPC's guiding principles included in the act are "supporting sustainable uses of the coast" and "improving the protection, conservation, restoration, and management of coastal and ocean ecosystems" [12]. To meet their mandate, the OPC began investigating ways to incorporate non-market values into legislative proposals, budgeting procedures, and regulatory and permitting processes. Non-market values were sought for features and uses including marine protected areas, offshore aquaculture, coastal zone management, wetlands preservation, different fishing methods, eradication of non-native invasive species, and restoration of wild salmon (*Oncorhynchus* spp.) populations.

The staff of the OPC sought a scientifically defensible, spatially explicit, simple, and replicable method for determining economic values of ecosystem services in coastal California. To meet internal agency standards and to withstand legal challenges, they desired that the method be widely accepted in the scientific peer-reviewed literature. The agency considered it critical that the values be spatially explicit because projects are proposed for specific locations and trade-offs are typically presented quantitatively in terms of area of land and water. Moreover, project proponents typically present anticipated benefits in terms of job creation or tax revenue associated with an explicit location. A simple method was considered necessary to accommodate the required speed of decision making. To be useful, economic values for ecosystem services must be available early in the decision process. The OPC required that methods be replicable so all projects under its jurisdiction could be assessed in a consistent manner.

2. Methods

We reviewed existing methods for what we considered relatively simple assessment and valuation of ecosystem services. When it became clear that many of the existing methods were too time-consuming for OPC staffers charged with obtaining the values, we developed an approach that would provide values for the ecosystems under OPC's jurisdiction. We first developed a matrix in which the rows represent classes of ecosystem services (following the MEA classifications) and the columns represent types of marine ecosystems found along the California coast (Appendix A).

We searched the economics literature on ecosystem service valuation to determine what values people worldwide hold per unit of area for these ecosystems, and which ecosystem services are generating those values. We included both peer-reviewed journal articles and gray literature. The Environmental Valuation Reference Inventory (https://www.evri.ca/) was our principal source of literature. We initially used keyword searches to select 73 articles as potentially salient and, after further screening, reviewed quantitative estimates from 35.

We assessed whether the values for given services, in given ecosystems, could be reasonably approximated by applying the replacement cost or the avoided cost method. The replacement cost method estimates the economic value of benefits currently provided by an ecosystem by calculating what it would cost to replace the existing ecosystem with either a built substitute or a restored system [13]. The avoided cost method calculates potential damages to human life or property, such as those from flooding, that would likely be prevented by maintaining a functioning ecosystem [14]. These methods are potentially attractive to decision-makers because they are relatively transparent, rapid, and inexpensive. However, the methods may not yield reliable information when the service cannot actually be replaced, or when the cost of a replacement system greatly exceeds the current service value. Some research suggests that replacement cost might be misleading or at least insufficient for ecosystem service valuation in specific circumstances [15]. These methods also might produce unreliable results because they calculate the costs of replacement, not the value of benefits lost. Costs associated with replacement and lost benefits are two different concepts, and their quantitative values are not necessarily similar. Because the replacement cost and avoided cost methods are controversial, we discussed which services might be partially replaceable via technology and developed guidance on use of the methods by OPC.

The group agreed that replacement or avoided cost tends to underestimate the actual total economic value of an ecosystem service. In cases where it was at least ostensibly possible to replicate the service, we agreed that replacement cost could serve as a proxy for part of its value. Ornamental resources, for example shells, could be cultivated artificially should habitat for the animals be destroyed. Replacement or avoided cost was deemed appropriate for some regulating services. These services sometimes have an existing built substitute, such as waste treatment plants, rip-rap erosion control, or air purification technology. The group agreed that climate could be regulated to a certain extent via emissions control and agricultural policy. The same criteria were applied for avoided cost. Values from the loss of services such as water purification are fairly straightforward to ascertain from market data.

The replacement or avoided cost methods were deemed inappropriate in the case of services for which a built or engineered solution did not seem reasonable. Cultural values, for example, often develop over time through human interactions with specific natural areas. Replacing these natural areas might be acceptable to some individuals. However even those replacements could require considerable time before the new area provided the values of the original area. Supporting services in general were deemed to require inputs from such extensive areas that they could not viably be replaced. Finally, the group decided that replacement or avoided cost was not usable for services with an explicitly non-domesticated component, including genetic resources, which tend to be more diverse in wild stocks than captive or artificially reared stocks, were deemed not amenable.

3. Results

The available information on values per unit area of coastal and marine ecosystems worldwide is limited in three ways. First, most reported estimates of non-market environmental values are associated with beaches and estuaries, with few if any reported values for other ecosystem types such as the rocky intertidal zone, deep shelf, or deep-sea vents. Second, much of the valuation research does not address specific ecosystem services.

Third, among the 35 articles we located, only 6 (17%) expressed values per unit area. Most studies focus on a specific but spatially undelineated area, such as a group of beaches in southern California, or an ecosystem that is presumably understood by survey respondents but is not spatially defined by the researchers. Values placed on these resources, or on hypothetical changes to them, are often expressed in terms of money per person, but the actual units in which value is measured varied widely among the 35 articles (Table 1).

Table 1
Number of studies using different units of measure to value marine ecosystem services.

Ecosystem service dimension:	Time dimension:			
	Per year	Per use	One-time	Unclear, aggregate
Spatially explicit:				
Per unit area (Acre, hectare)	4		2	
Person-related:				
Per person	1	3	3	
Per household	8	2		
Per user (angler, visitor, party, respondent)	3	2		
Other:				
Per unit of resource (fish)		1		
Per aggregate resource (coastline, bay, species in a region)	1		2	
Per business enterprise	1			
Per residential property			1	
Unclear, aggregate				1
			Total:	35

Table 2
Ecosystem service values reported in the peer-reviewed and gray literature for beaches and estuaries.

Service category[a]	Service value (2008 US$ per acre per year)	
	Beaches	Estuaries
Provisioning		
Capture fisheries		55–81[b]
Wild plant and animal products		26[c]
Regulating		
Erosion regulation	31,131[d]	
Natural hazard regulation		278–332[e]
Cultural		
Cultural heritage values	27[f]	17[g]
Recreation and ecotourism	16,946[h]	8–346[i]
Supporting		
Habitat and refugia[j]		77–415[k]
Primary production		1,102–1,833[l]
Water cycling		56[m]
Bundled attributes[n]	36,000–83,000[o]	421–817[p]

[a] Service categories from [5]. Only those services for which we found spatially explicit estimates are shown.
[b] Low value: [26]; high value: [27].
[c] [26].
[d] [19].
[e] Derived from [26]. Range results from different rates of future population growth.
[f] [19].
[g] [28].
[h] [19].
[i] Low value: [28]; high value: [28].
[j] Habitat and refugia is not a category recognized by the MEA, but habitat values of estuaries are often discussed in the valuation literature.
[k] Low value[28]); high value: [19].
[l] Derived from [19]. Range results from different primary productivity among ecosystem subtypes.
[m] [19].
[n] Bundled attributes refers to cases in which people were asked to value ecosystem services generally, rather than by category.
[o] [19]. Range results from use of different discount rates to convert one-time asset values into annual service values.
[p] Low value:[26]; high value: [18].

Reported values per unit area for beaches and estuaries vary widely (Table 2). We considered 11 additional ecosystem types. Of those 11 we found spatially explicit values for marshes, rocky

Table 3
Ecosystem services deemed amenable (*X*) or not amenable (–) to estimation using the avoided cost and replacement cost methods.*

Service category	Marsh	Beach	Mud flat	Lagoon/ salt pond	Estuary	Rocky intertidal	Kelp	Rocky reef	Shell reef	Seagrass	Inner shelf	Outer shelf, edge, slope	Seamount and mid-ocean ridge
Provisioning													
-Capture fisheries													
-Aquaculture			X	X	X	X	X	X	X	X	X	X	X
-Wild plant & animal products	–	–	–	–	–	–	–	–	–	–	–	–	–
Genetic resources	–	–	–	–	–	–	–	–	–	–	–	–	–
Biochemicals, medicines	–	–	–	–	–	–	–	–	–	–	–	–	–
Ornamental Resources	X	X	X	X	X	X	X	X	X	X	X	X	X
Human habitation													
Human navigation													
Energy (for human use)	X	X	X	X	X	X	X	X	X	X	X	X	X
Regulating													
Air quality regulation	X	X	X	X	X	X	X	X	X	X	X	X	X
Climate regulation	X	X	X	X	X	X	X	X	X	X	X	X	X
Erosion regulation	X	X	X	X	X	X	X	X	X	X	X	X	X
Water purification, waste treatment	X	X	X	X	X	X	X	X	X	X	X	X	X
Disease regulation													
Pest regulation					X	X	X	X	X	X	X	X	X
Pollination/ seed dispersal													
Natural hazard regulation	X	X	X	X	X	X	X	X	X	X	X	X	X
Freshwater storage/retention	X	X	X	X	X	X	X	X	X	X	X	X	X
Gas regulation	X				X	X	X	X	X	X	X	X	X
Cultural													
Cultural diversity	–	–	–	–	–	–	–	–	–	–	–	–	–
Spiritual & religious values	–	–	–	–	–	–	–	–	–	–	–	–	–
Knowledge systems	–	–	–	–	–	–	–	–	–	–	–	–	–
Educational values	–	–	–	–	–	–	–	–	–	–	–	–	–
Inspiration	–	–	–	–	–	–	–	–	–	–	–	–	–
esthetic values	–	–	–	–	–	–	–	–	–	–	–	–	–
Social relations	X	X	X	X	X	X	X	X	X	X	X	X	X
Sense of place	–	–	–	–	–	–	–	–	–	–	–	–	–
Cultural heritage values	–	–	–	–	–	–	–	–	–	–	–	–	–
Recreation and ecotourism	X	X	X	X	X	X	X	X	X	X	X	X	X
Supporting													
Photosynthesis	–	–	–	–	–	–	–	–	–	–	–	–	–
Primary production	–	–	–	–	–	–	–	–	–	–	–	–	–
Nutrient cyclic	–	–	–	–	–	–	–	–	–	–	–	–	–
Water cycling	–	–	–	–	–	–	–	–	–	–	–	–	–

* Blank cells indicate that no consensus was reached by the working group during the limited time available for discussion.

reefs, shell reefs, seagrass, inner shelves, and outer shelves, edges, and slopes (Appendix A). We found reported values that were not spatially explicit for mudflats, lagoons and salt ponds, and rocky intertidal systems. We did not find any reported values in the literature for kelp, seamounts and mid-ocean ridges, deep sea and central gyres, and deep sea vents.

We reached a general consensus that, at least in California, values for some types of services provided by some ecosystems can likely be approximated by applying the avoided cost and replacement cost methods (Table 3).

4. Discussion

Our results suggest there is a dearth of spatially explicit non-market values for services provided by coastal and other ecosystems. Given the variability of the values reported in the existing literature, we suggest original valuation be applied to each spatially explicit area that will be affected by a given policy decision. The objective of most non-market valuation research to date has been to assess how one or more specific changes in ecosystem services affect the welfare of individuals or households. Although contingent valuation surveys usually specify these potential changes in some detail so respondents can be presumed to understand what they are being asked to value, the precise spatial extent of the changes may not be an explicit element of the survey. For some changes, such as improvements in water quality or protection of migratory species, spatial dimensions may be inherently subjective or ambiguous. For other changes, such as potential closure of a popular beach, the spatial dimensions may be assumed to be known by the users, or are measurable by the researchers, but are not reported in the study. The same considerations hold for travel cost research; the data in many studies may simply have been insufficient to permit estimation of spatially explicit values, or the researchers did not carry out the necessary calculations, or did not report the calculations. Some recent studies, such as Costanza et al. [19], pay much closer attention to the spatial dimensions of values.

Our findings are consistent with other recent reviews. Beaumont et al. [16], reporting on the value of biological diversity in the United Kingdom, found four categories of services without valuation data: cultural heritage and identity, option use value, resilience and resistance, and biologically mediated habitat. Pendleton [6] reviewed 300 possible sources of valuation research relating to coastal ecosystems and found that 75% did not explicitly address the economic values of coastal ecosystem services. Katsanevakis et al. [17] also reviewed the literature and found relatively few marine environmental valuation studies, most of which focus on beaches. Furthermore, even when ecosystem services were directly addressed in valuation efforts, the services often were not described or valued in a spatially explicit manner.

Accurately and spatially explicitly valuing marine ecosystem services is challenging for many reasons, and there is some disagreement about the scientific validity of valuing ecosystem services on a per unit area basis [18]. Marine systems are often interconnected at a very large spatial scale, and what is considered a relevant management unit might rely on inputs from considerable distances. An estuary may be valuable for a fishery, but that fishery is not supported by just the estuary – the fish may migrate to the estuary, or the fishery may benefit from fresh water inputs. That these systems are often interdependent at a scale beyond that managed by any one agency is a fundamental difficulty of non market valuation. Continued interdisciplinary work with natural scientists from the appropriate disciplines will certainly help economists refine their methods to reflect the ecological reality of any valuation scenario. In the meantime, however, regulatory agencies and policy makers must make decisions about specific projects, such as roads or housing developments, with known spatial footprints.

Variation across studies in the estimated economic values of ecosystem services does not mean that the methods applied in those studies were flawed. The exact definition of the services being valued varied, as did the characteristics of the population holding the values. Prices of identical market goods, such as gasoline and some prescription drugs, vary among regions and countries. Variation in survey type and payment option will also affect values [16]. It is possible that different methods for valuing the same service in the same location will yield different values. The variability of estimated values suggests that original, site-specific valuation studies are needed to obtain accurate values. In addition, the total value per unit area of an ecosystem used by many people will likely be greater than the value per unit area of a similar ecosystem used by fewer people. For these reasons, it may not be credible to use existing but incomplete data (Table 2 and Appendix A) to rank the importance of ecosystems or services for policy purposes.

The OPC sought a relatively simple method for ascertaining non-market values. We initially considered creating a table that could be populated with values to provide an upper and lower bound for values of different services in different ecosystems, ideally given different qualitative or quantitative characterizations of ecosystem status. The OPC envisioned such a table, with underlying documentation, as analogous to a balance sheet that could inform decisions about project permits and terms. The table would have served as a tool for conducting what is known as value transfer analysis, in which non-market values determined in one study are applied to other situations [20]. However, we determined that the current literature on coastal ecosystem service values is not sufficient to populate such a table. Although it might be possible to generate generic values for some services provided by some ecosystems, we felt that to do so would be irresponsible given the paucity of applicable published results. Non market valuation is not always appropriate for an application wherein existing values can be easily compiled and used in new, unrelated cases. Non market valuation methods are, however, reasonably well developed and are appropriate for use in original research.

Original research also fulfills the requirements of standard guidance for cost–benefit analysis [21–23]. This guidance recommends that the responsible agency ascertain values from a sample of people in a geographic area sufficiently extensive that the sample can adequately represent all salient stakeholders. The OPC believes that, for its purposes, all salient stakeholders includes all California citizens. It would be jurisdictionally inappropriate for a particular state agency to adopt reported ecosystem service values derived from small or distant groups of people and expect those values to adequately represent the preferences of Californians. That type of extra-regional valuation might be appropriate for certain types of trans-boundary effects or for evaluation by agencies or groups whose jurisdiction is in fact national, such as US federal agencies.

As a possible next step toward service values that can be used for policy decisions, an agency could prioritize which ecosystems and which services are most relevant to current management and policy initiatives in a given jurisdiction. This has been suggested by others, including Katsanevakis et al. [17]. The OPC's most recent strategic plan does not explicitly prioritize ecosystem types, but some OPC staff members suggest that priority types include tidal wetlands and beaches affected by erosion.

Spatially explicit data on land cover exist for most of the United States at relatively high resolution (e.g., 30-m), although map accuracy varies among land-cover types. Contiguous areas of a given land-cover or ecosystem type often can be delineated into patches or polygons. In some cases, it is possible to estimate the status of a given ecosystem service provided within that polygon. For example, one might estimate the status of a given species of fish (a provisioning service) on the basis of data on the location and density of eelgrass (*Zostera* spp.), which provides habitat for many fishes of commercial and recreational importance. The ability of an estuary to provide the regulating services of water purification and waste treatment might be estimated on the basis of areal cover of marshes as well as the extent of impervious surfaces in adjacent catchments. The Albemarle/Pamlico National Estuary Program has used spatially explicit data on submerged aquatic vegetation to map the location of several supporting services provided by estuaries, including nitrogen cycling and net primary production [24]. Once services are mapped and their qualitative or quantitative status is estimated, it is possible to conduct spatially explicit valuation research related to current status or potential changes in status.

We believe 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 U.S. 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 on the status and value of ecosystem services are more robust than estimates at the level of, say, $10\ \mathrm{km} \times 10\ \mathrm{km}$ grids. If necessary, it would be analytically tractable to aggregate values for multiple watersheds within a county or a similar political unit.

Different methods of economic valuation are applicable to different ecosystem services. A panel of economists convened by the U.S. National Oceanic and Atmospheric Association (NOAA) provided guidance on applying the contingent valuation method to value passive use losses in cases such as the Exxon Valdez oil spill [25]. As a result of that report and case law, the contingent valuation method is accepted as the standard method for valuation in federal courts in the United States. Whereas avoided cost or replacement cost methods can provide credible values of some types of services, these methods do not capture all of the values consistently provided by an ecosystem. Because cultural services typically generate non-use values, they must be quantified using stated preference methods such as contingent valuation or choice experiments. Given possible variations in response to particular methods, we recommend consistently matching methods to service type to ensure greater comparability of values. This would mean method specificity at the level not just of stated as opposed to revealed preference, but choice experiment as opposed to contingent valuation.

We found that in most cases it is possible to achieve consensus among economists and ecologists about which ecosystem services are amenable to valuation by replacement or avoided cost methods. By pursuing similar discussions within and among agencies and stakeholders, it may be possible to reach general agreement about which ecosystem services can be valued relatively rapidly or inexpensively. These methods can be less costly than other, survey-based methods. Additionally, the policymakers in our group pointed out that certain stakeholders find replacement cost estimates to be more credible than stated preference methods, which produce hypothetical results.

Ease of valuation does not correspond with importance of a given service, nor will replacement cost adequately describe the total economic value of any ecosystem service. Only place-based, original, high quality valuation studies of specific prioritized services in specific ecosystems can substantially improve the available scientific information for policy decisions affecting those ecosystems.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2012.01.005.

References

[1] Shogren JF, et al. Why economics matters for endangered species protection. Conserv. Biol. 1999;13:1257–61.
[2] Mascia MB, Brosius JP, Dobson TA, Forbes BC, Horowitz L, McKean MA, et al. Conservation and social sciences. Conserv. Biol. 2003;17:649–50.
[3] Freeman III AM. The Measurement of Environmental and Resource Values. Washington, D.C: Resources for the Future; 1993.
[4] Champ PA, Boyle KJ, Brown TC, editors. A Primer on Nonmarket Valuation. Dordrecht, The Netherlands: Kluwer Academic Publishers; 2003.
[5] Millennium Ecosystem Assessment. Ecosystems and Human Well-Being: Synthesis. Washington, D.C.: Island Press; 2005.
[6] Pendleton L, editor. The Economic and Market Value of Coasts and Estuaries: What's at Stake? Washington, DC: Restoring America's Estuaries; 2007.
[7] State of California. 2010a. California Code of Regulations. 14 C.C.R. § 15131. Available from 〈http://www.oal.ca.gov/CCR.htm〉 (accessed July 2010).
[8] State of California. 2010b. California Water Code. Section 13000. Available from 〈http://www.leginfo.ca.gov/cgi-bin/calawquery?codesection=wat&codebody=&hits=20〉 (accessed July 2010).
[9] Executive Order 12893Principles for federal infrastructure investments, at Section 2(a)1. 59 Fed. Reg. 4233 (Jan. 31, 1994). Available from 〈http://www.archives.gov/federal-register/executive-orders/pdf/12893.pdf〉 (accessed July 2010).
[10] Institute for Water ResourcesNational economic development procedures manual—overview manual for conducting national economic development analysis. Fort Belvoir, VA: U.S. Army Corps of Engineers, Water Resources Support Center, Institute for Water Resources; 1991.
[11] Institute for Water ResourcesNational economic development procedures manual—national economic development costs. Fort Belvoir, VA: U.S. Army Corps of Engineers, Water Resources Support Center, Institute for Water Resources; 1993. Available from 〈http://www.iwr.usace.army.mil/docs/iwrreports/93r12.pdf〉 (accessed July 2010).
[12] 〈http://www.opc.ca.gov/webmaster/ftp/pdf/docs/OPC_Strategic_Plan_2006.pdf〉 accessed November 2010.
[13] Farber S, Costanza R, Childers DL, Erickson J, Gross K, Grove M, et al. Linking ecology and economics for ecosystem management. Bioscience 2006;56:121–33.
[14] Farber SC, Costanza R, Wilson MA. Economic and ecological concepts for valuing ecosystem services. Ecol. Econ. 2002;41:375–92.
[15] National Research Council. Valuing Ecosystem Services: Toward Better Environmental Decision-Making. Washington, D.C.: National Academies Press; 2004.
[16] Beaumont NJ, Austin MC, Mangi SC, Townsend M. Economic valuation for the conservation of marine biodiversity. Mar. Pollut. Bull. 2008;56:386–96.
[17] Katsanevakis S, Stelzenmüller V, South A, Sørensen TK, Jones PJ, Kerr S, et al. Ecosystem-based marine spatial management: review of concepts, policies, tools, and critical issues. Ocean Coast. Manage. 2011;54:807–20.
[18] Farley J. The role of prices in conserving critical natural capital. Conserv. Biol. 2008;22:1399–408.
[19] Costanza R, Wilson M, et al. The value of New Jersey's ecosystem services and natural capital. New Jersey Department Environ. Prot. 2006.
[20] Akter S, Grafton RQ. Confronting uncertainty and missing values in environmental value transfer as applied to species conservation. Conserv. Biol. 2010;24:1407–17.
[21] Pearce D, Atkinson G, Mourato S. Cost-Benefit Analysis and the Environment: Recent Developments. Paris, France: Organization for Economic Cooperation and Development; 2006.
[22] Vining AR, Boardman AE. The choice of formal policy analysis methods in Canada. In: Dobuzinskis L, Howlett M, Laycock D, editors. Policy Analysis in Canada: The State of the Art. Toronto: University of Toronto Press; 2007In: Dobuzinskis L, Howlett M, Laycock D, editors. Policy Analysis in Canada: The State of the Art. Toronto: University of Toronto Press; 2007.
[23] Hahn RW, Tetlock PC. Has economic analysis improved regulatory decisions? J. Econ. Perspect. 2008;22:67–84.
[24] USEPA (U.S. Environmental Protection Agency). 2010. Albemarle-Pamlico Watershed Study (APWS). EPA Ecosystem Services Research Group. Available from 〈http://www.epa.gov/ord/esrp/quick-finder/apws-research.htm〉 (accessed July 2010).
[25] Arrow K, et al. Report of the NOAA Panel on Contingent Valuation. 〈http://www.darrp.noaa.gov/library/pdf/cvblue.pdf〉, accessed 11/2008.
[26] Costanza R, Farber SC, Maxwell J. Valuation and management of wetland ecosystems. Ecol. Econ. 1989;1:335–61.
[27] Farber S, Costanza R. The economic value of wetlands systems. J. Environ. Manage. 1987;24:41–51.
[28] Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, et al. The value of the world's ecosystem services and natural capital. Nature 1997;387:253–60.