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INTEGRATED ASSESSMENT AND VALUATION OF ECOSYSTEM GOODS AND SERVICES PROVIDED BY COASTAL SYSTEMS

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ABSTRACT

The goods and services provided by coastal systems and the natural capital stocks that produce them are critical to the functioning of the earth's life support systems. They also contribute significantly to human welfare, both directly and indirectly, and therefore represent a significant portion of the total economic value of the global environment. Coastal systems including estuaries, coastal wetlands, river deltas and coastal shelves are particularly rich in ecosystem goods and services. They provide a wide range of highly valued resources including fisheries, open spaces, wildlife habitat, nutrient cycling, and recreational opportunities. In this paper, we present a conceptual framework for the assessment and valuation of goods and services provided by coastal systems. First, we elucidate a formal system based on functional diversity for classifying and valuing coastal ecosystem services, emphasizing that no single ecological or economic methodology can capture the total value of these complex systems. Second, we demonstrate the process of ecosystem service valuation using a series of economic case studies and examples drawn from peer-reviewed literature. We conclude with observations on the future of coastal ecosystem service valuation and its potential role in the science and management of coastal zone resources.

INTRODUCTION

Throughout history, humans have favored coastal locations as desirable places to live, work, and play. Forming a dynamic zone of convergence between land and sea, the coastal regions of the earth serve as unique geological, ecological and biological domains of vital importance to a vast array of terrestrial and aquatic life. Given this abundance, it is perhaps not surprising that the coastal zone (≤ 150km of the coastline) has long served as a focal point for human activity.

Early on, estuaries and inlets served as places of relative shelter that also provided staging areas for harvesting food and fibre. As trading between human settlements developed, ports grew up in those places that offered sea-going vessels protection and provided access to the interior via freshwater river systems. The industrial revolution increased the use of the coastal zone not only for the transport of raw materials and finished goods, but also in new uses such as water extraction and the discharge of waste. With the recent ascendance of post-material society, recreational aspects of the coastal zone have increased in importance, as inland waterways, stretches of beach, coral reefs and rocky cliffs provide opportunities for leisure activity.

Coastal areas around the world are currently undergoing significant human population growth pressures. Approximately 44% of the global population in 1994 lived within 150 km of a coastline (Cohen *et al.* 1997). Today, that trend appears to be accelerating. Already, more than half of the United States population lives along the coast and in coastal watersheds (Beach 2002). Coastal states in the U.S. are among the nation's fastest growing and are expected to experience most of the absolute growth in population in the decades ahead (Beatley *et al.* 2002). The overwhelming majority of Chinese (94%) live in the eastern third of China and over 56% reside in coastal provinces along the Yangtze river valley, and two coastal municipalities – Shanghai and Tianjin (Hinrichsen 1998). In Europe, according to projections worked out by the Mediterranean Blue Plan (*http: //www.planbleu.org/indexa.htm*), the Mediterranean Basin's resident population could go as high as 555 million by 2025. These projections clearly show that coastal regions within the Mediterranean could reach 176 million – 30 million more than the entire coastal population in 1990.

Today, there are few, if any, coastal regions that have not been affected in some way by human intervention (Vitousek *et al.* 1997). Just the fact that so many people live in the coastal zone is a form of pressure on the natural structures and processes that provide the goods and services people desire. Moreover, humans are now a major agent influencing the morphology and ecology of the coastal zone either directly by means of engineering and construction works and/or indirectly by modifying the physical, biological and chemical processes at work within the coastal system (Townend 2002).

The population and development pressures that coastal areas are now experiencing raise significant challenges for coastal planners and decision makers. Communities must often choose between competing uses of the coastal environment and the myriad goods and services provided by healthy, functioning ecosystems. Should this shoreline be cleared and stabilized to provide new land for development, or should it be maintained in its current state to serve as a wildlife habitat? Should that wetland be drained and converted to agriculture or should more wetland area be created to provide freshwater filtration services? Should this coral reef be mined for building materials and the production of lime, mortar and cement or should it be sustained to provide renewable seafood products and recreational opportunities?

To choose from among these competing options, it is important to know not only what ecosystem goods and services will be affected but also what they are actually worth to different members of society. When confronting decisions that pit different ecosystem services against one another, decision makers cannot escape making a *social choice* based on values: whenever one alternative is chosen over another, that choice indicates which alternative is deemed to be worth more than other alternatives. In short, "we cannot avoid the valuation issue, because as long as we are forced to make choices, we are doing valuation" (Costanza and Folke 1997 p. 50). Thus, without efforts to assess and quantify *all* the benefits associated with coastal ecosystem goods and services, policy and managerial decisions will ultimately be skewed in favor of environmentally degrading practices by neglecting the diffuse social interests that benefit from the non-use characteristics of such systems.

1. CONCEPTUAL FRAMEWORK

Coastal systems such as estuaries, rivers, wetlands and beaches provide many different goods and services to human society. An ecosystem service, by definition, contains all "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily 1997). Ecosystem goods, on the other hand, represent the material products that are obtained from natural systems for human use (DeGroot *et al.* 2002). Ecosystem goods and services occur at multiple scales, from climate regulation and carbon sequestration at the global scale, to flood protection, water supply, soil formation, nutrient cycling, waste treatment and pollination at the local and regional scales (DeGroot *et al.* 2002). They also span a range of degree of direct connection to human welfare, with those listed above being less directly connected, while food, raw materials, genetic resources, recreational opportunities, and aesthetic and cultural values are more directly connected. For this reason, ecologists, social scientists and environmental managers are increasingly interested in assessing the economic values associated with ecosystem goods and services associated with coastal systems (Bingham *et al.* 1995; Costanza *et al.* 1997; Daily 1997; Farber *et al.* 2002).

Figure 1 represents an integrated framework we have developed for the assessment of ecosystem goods and services within the coastal zone, including consideration of ecological structures and processes, land use decisions, human welfare and the feedbacks between them. As the schematic shows, ecosystem goods and services form a pivotal conceptual link between human and ecological systems. Ecosystem structures and processes are influenced by long-term, large-scale biogeophysical drivers (e.g., tectonic pressures, global weather patterns) which in turn create the necessary conditions for providing the ecosystem goods and services people value. The concept of ecosystem goods and services

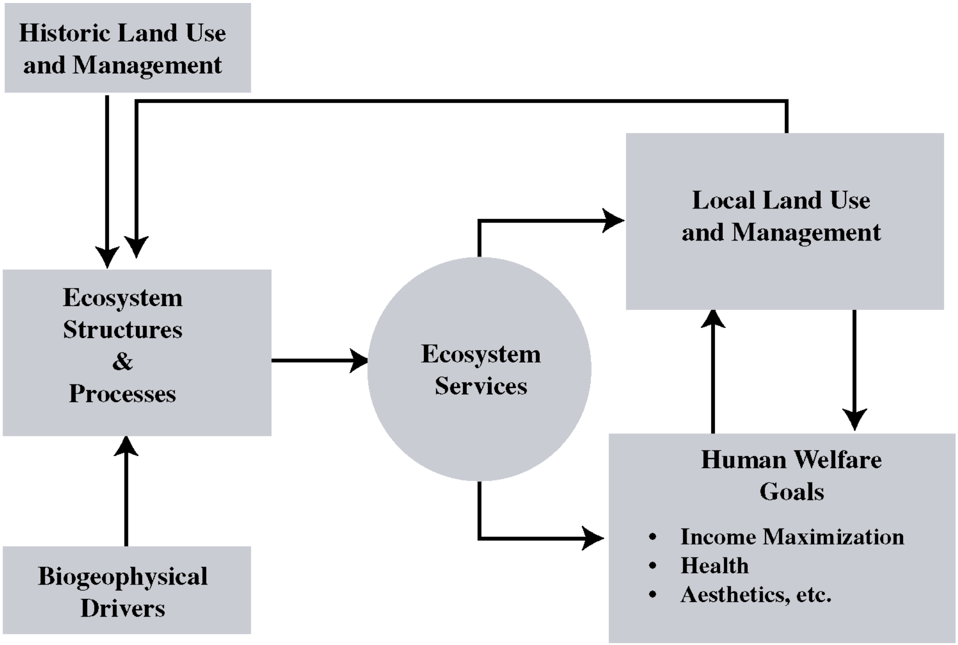

Figure 1. Framework for integrated assessment and valuation of ecosystem functions, goods and services in the coastal zone

used in this paper is inherently *anthropocentric:* it is the presence of human beings as welfare-maximizing agents that enables the translation of basic ecological structures and processes into value-laden entities. Through laws and rules, land use management and policy decisions, individuals and social groups make tradeoffs between these values. In turn, these land use decisions directly modify the structures and processes of the coastal zone by engineering and construction and/or indirectly by modifying the physical, biological and chemical processes of the natural system (Boumans *et al.* 2002).

The concept of ecosystem goods and services is useful for coastal zone science and management for three fundamental reasons. First, it helps us synthesize essential ecological and economic concepts, allowing researchers and managers to link human and ecological systems in a viable and policy relevant manner. Second, it draws upon the latest available economic methods for economic valuation. Third, scientists and policy makers can use the concept to evaluate social and political tradeoffs between coastal land use development and conservation alternatives. In this paper, we use the concept of goods and services to describe a diversity of human values associated with coastal systems. In particular, we focus on the estimation of *economic* values and how these values can be used to inform decisions about the future of the coastal zone.

2. DEFINING THE ECOLOGICAL STRUCTURES, PROCESSES AND HABITATS IN THE COASTAL ZONE

Coastlines around the world exhibit a variety of physical types and characteristics, the result of major differences in geology and biophysical processes. There are also a number of distinct habitat and ecosystem types within the coastal zone, each suggesting unique management and planning needs. As mentioned previously, coastal regions are dynamic interface zones where land, water and atmosphere interact in a fragile balance that is constantly being altered by natural and human influences. When establishing classification schemes for the coastal zone, it is important to remember that critical biological and physical drivers and interconnections extend beyond these areas and that coastal zones can be significantly affected by events that happen great distances (temporal and spatial) from the coast itself.

Accurate land cover/land use definition and classification are essential preliminary steps in the valuation and management of coastal systems. When designing and implementing a classification system, a balance is struck between the use of *a priori* and *post priori* schemas. While the former provides a greater degree of standardization and consistency, the latter provides greater flexibility by allowing the end user to adopt the system to unique spatiotemporal contexts. In this paper, we strike a balance between the two by using a global land use classification system with a high level of standardization and adapt that system to a recently developed typology of ecosystem goods and services (DeGroot *et al.* 2002).

The landscape classification is based on the strategy outlined by the UN's Food and Agricultural Organization Land Cover Classification System (LCCS) for terrestrial systems amended to account for attributes specific to coastal systems (see http://www.lccs-info.org/) (Di Gregorio and Jansen 2000). Coastal attributes were modified using the typologies of the "Land-Ocean Interactions in the Coastal Zone" (LOICZ) program (http://www.nioz.nl/loicz/info.htm) and "The Coastal Systems of Europe" (CSE) developed under the auspices of the European Coastal and Marine Ecological Network (ECMEN) (http://www.coastalguide.org/csm/index.html).

The FAO-LCCS program defines land cover as "the observed biophysical cover on the earth's surface" including vegetation and man-made features as well as bare rock, bare soil and inland water surfaces (Di Gregorio and Jansen 2000). Because most extant land cover classifications in the literature are spotty with respect to quality, scale and nomenclature, and class definitions are often imprecise, ambiguous and/or absent with a limited ability to accommodate the whole range of possible phenomena, the LCCS team designed a system that seeks to provide common, internationally applicable standards. The LCCS program is the first to provide a comprehensive framework for the description, characterization, classification and comparison of all non-oceanic land covers identified anywhere in the world, at any scale.

While terrestrial land covers in coastal zones are readily classified using the existing LCCS system, oceanic features are not. Extending the LCCS objective of a creating a classificatory system that harmonizes and standardizes the collection of land cover data worldwide, we have borrowed from the aforementioned LOICZ typology those attributes that are specific to the coastal zone and merged it with the extant LCCS system. The LOICZ project is one of eleven "Program Elements" in the International Geosphere-Biosphere Project and focuses specifically on the coastal zone. The availability of a global, geo-referenced LOICZ database allowed for the use of several key attributes within the coastal zone: wave heights, tidal type, tidal range, salinity specifications, ocean currents, morphologic characteristics and presence/absence of coral reefs.

Additionally, where necessary, we have employed the classification of coastal systems illustrated by "Coastal Systems of Europe" (CSE). For example, the LOICZ typology only differentiates between narrow and wide coastal shelfs (smaller or wider than 50 km) classifying slope features of the coastline as mountainous, hilly, or plain and identifies the presence/absence of reefs, glacial ice or deltas. The CSE system provides significant additional information about the attributes of predominant *substrates* in the coastal zone. CSE subdivides the littoral zone into (a) hard rocks, (b) soft rocks (c) recent sediments and uses slope features to distinguish between inter-tidal and supra-tidal habitats.

Specific coastal landscape features are identified under this synthesized typology. For example, hard rock on cliffed coasts is most likely represented by sea cliffs, cliff islands, archipelagos, fjords and sea lochs, rias, rocky shores with caves, bay and pocket dunes, river mouths, small estuaries and embayments. Hard rock on coastal plains is more characteristic of skerry coasts, fjords, river mouths, arctic tidal plains, and karstic shores. Once landscape features are identified, it is possible to associate ecological habitats and ecosystem types with them (see Table 1). The general class, "coastal zone" harbors sub and intertidal habitats as well as supra tidal habitats. Because supra tidal habitats such as forests, urban areas and agriculture are not unique to the coastal zone, we do not include them within our analysis. Sub and Intertidal habitat classifications recognized for Europe are: cliffs, stony banks and shingles, kelp forests, estuaries, sea dunes, sandbanks, salt marshes, mud and sand flats, lagoons, and sea grass beds. Additional habitats included for tropical regions are corals and mangrove forests.

Table 1 below presents results from cross-referencing ecosystem goods and services against coastal landscape features and habitats. Following the differentiation between structure and process noted above, we have separated coastal landscape features from their associated habitats because geomorphology and landscape structure provide different ecosystem goods and services than those provided by ecological habitats. For example, mismanagement of a river habitat could devoid the river of living organisms and severely impact those ecosystem services associated with the ecological habitat of the river system – e.g., nutrient uptake and wildlife refugium – while leaving water regulation, flood prevention and transportation values untouched. An accurate land-cover classification needs to be able to delineate whether or not ecosystem services are derived from landscape features or habitat to prevent the danger of double-counting (see below section 4).

The information depicted in Table 1 shows that ecosystem good and service values can be associated with either landscape features or habitats or both. Open circles represent potential ecosystem goods and services provided by landscape features and habitats. Closed circles, on the other hand, represent ecosystem goods and services that have been empirically

Table 1: Landscape Types, Habitats, Goods and Services in the Coastal Zone

	Ecosystem services																			Ecosystem goods				
	Gas regulation	Climate regulation	Disturbance prevention	Water regulation	Water supply	Soil retention	Soil formation	Nutrient regulation	Waste treatement	Pollination	Biological control	Habitat functions	Refugium function	Nursery function	Aesthetic information	Recreation	Cultural and artistic info	Spiritual and Historic info	Science and Education	Food	Raw materials	Genetic resources	Medical resources	Ornamental resources
Landscape features																								
cliffs			○									○	○	○	○	○	○		○		○			○
fjords_lochs_rias			○									○	○	○	○	○		○			○			○
estuaries	○		○	●	●			●	●			○	○	○	○	●				●	●			○
Ice coasts		○										○	○	○	○				○					
tidal plains			○	○				○	○			○	○	○	○	○	○			○				
barrier coast			●									○	○	○	○	○		○		○				○
lagoons	○	○	○	○				○				○	○	○	○	○	○	○		○				○
dunes	○		○		○							○	○	○		○	○		○		○			
deltas	○	○	○	○	○		○	○	○			○	○	○	○	○	○	○	○	○	○			
beaches			●			○						○	○		●	●	○	○						
Habitats																								
Intertidal																								
Cliffs			○										○	○	○	○			○					
Shingle			○										○	○	○	○				○				
Kelp	○		○			○		○			○		○	○					○	○	○			○
Seagrass	○		○			○		○					○	○	○				○	○				
Estuary	○	○	●					●	●		○		○	●	●	●			○	●				
Wetland	○	○	●	○	●		○	●	○		○		○	○	○	●			○	●				
Salt_marsh	○	○	○			○	○	●					○	○					○	●				
Mud_flat			●					○					○	○					○	○				
lagoons	○	○	○					○					○	○	○	○			○	○				
Mangrove	○	○	●	○				○	○				○	○	○	●	○		○	●	●	○	○	○
dunes	○		○	○		○	○	○					○	○	○				○	○	○			
Sandbank								○					○			○			○	○	○			
Coral								○			○		○	○	○	●	○		○	●	●	○	○	○

● = Economic Values Available in Peer-Reviewed Literature

○ = No Economic Values Available in Peet-Reviewed Literature, but Values Probable measured in the economic valuation literature. In this paper, we focus primarily on studies that have measured economic values for ecosystem goods and services.

3. ECONOMIC VALUATION OF COASTAL ECOSYSTEM GOODS AND SERVICES

In economic terms, the ecosystem goods and services depicted in Table 1 can potentially yield a number of important values to humans. When discussing these values, however, we first need to clarify what the underlying concept actually means. The term 'value' as it is employed in this paper has its conceptual foundation in economic theory (Freeman 1993). In this limited sense, value can be reflected in two theoretically commensurate empirical measures. First, there is the amount of money people are willing to pay for specific improvements in a good or service, *willingness to pay* (WTP). Second, there is the minimum amount an individual would need to be compensated to accept a specific degradation in a good or service, *willingness to accept compensation* (WAC) (Bishop *et al.* 1997). Simply put, economic value is the amount of money a person is willing to give up in order to get a thing, or the amount of money required to give up that thing. To date in the literature, WTP has been the dominant measure of economic value. However, WTP is not restricted to what we actually observe from people's transactions in a market. Instead, "it expresses how much people would be willing to pay for a given good or service, whether or not they actually do so" (Goulder and Kennedy 1997).

A central concern in coastal management is one of making social tradeoffs – allocating scarce resources among society's members. For example, if society wished to make the most of its endowment of coastal resources, it should be possible to compare the value of what society's members receive from any improvement in a given coastal ecosystem with the value of what its members give up to degrade the same system. The prevailing approach to this type of assessment in the literature is cost-benefit analysis (Ableson 1979; Kneese 1984; Turner 2000). Cost-benefit analysis is characterized by a fairly strict decision-making structure: "defining the project, identifying impacts which are economically relevant, physically quantifying impacts as benefits or costs" and then, "calculating a summary monetary valuation" (Hanley and Spash 1993). Given this approach, a key question comes down to: what gets counted?

In addition to the production of marketable goods, coastal ecosystems provide natural functions such as nutrient recycling as well as conferring aesthetic benefits on humans (Costanza *et al.* 1997). Coastal goods and services may therefore be divided into two general categories: (1) the provision of direct *market* goods or services such as drinking water, transportation, electricity generation, pollution disposal and irrigation; and, (2) the provision of *non-market* goods or services which include things like biodiversity, support for terrestrial and estuarine ecosystems, habitat for plant and animal life, and the satisfaction people derive from simply knowing that a beach or coral reef exists.

The market values of ecosystem goods and services are the observed trading ratios for services that are directly traded in the marketplace: price = exchange value. The exchange-based, welfare value of a natural good or service is its market price net of the cost of bringing that service to market. For example, the exchange-based value of fresh fish to society is based on its catch rate and "value at landing" which is the market price of fish, minus harvest and time management costs. Estimating exchange-based values in this case is relatively simple, as observable trades exist from which to measure value.

Since individuals can be observed making choices between objects in the marketplace while operating within the limits of income and time, economists have developed several market-based measures of value as imputations from these observed choices. While monetary measures of value are not the only possible yardstick, they are convenient since many choices involve the use of money. Hence, if you are observed to pay $9 for a pound of shrimp, the imputation is that you value a pound of shrimp to be at least $9, and are willing to make a trade-off of $9 worth of other things to obtain that shrimp. The money itself has no intrinsic value, but represents other things which could have been purchased. Time is often considered another yardstick of value; if someone spends 2 hours fishing, the imputation is that the person values the fishing experience to be worth more than 2 hours spent on other activities. Value is thus a resultant of the expressed tastes and preferences of persons, and the limited means with which objects can be pursued. As a result, the scarcer the object is, the greater its value will be on the margin.

By estimating the economic value of ecosystem goods and services not traded in the marketplace, however, social costs or benefits that otherwise would remain hidden or unappreciated are revealed. While measuring exchange values requires monitoring market data for observable trades, non-market values of goods and services are much broader and more difficult to measure. Indeed, it is these values that are have captured the attention of environmental and resource economists who have developed a number of techniques for valuing ecosystem goods and services (Bingham *et al.* 1995; Freeman 1993). When there are no explicit markets for services, more indirect means of assessing economic values must be used. A spectrum of economic valuation techniques commonly used to establish the WTP or WTA when market values do not exist are identified below.

As these brief descriptions suggest, each economic valuation methodology has its own strengths and limitations, thereby restricting its use to a select range of goods and services associated with coastal systems. For example, Travel Cost (TC) is useful for estimating recreation values, and Hedonic Pricing (HP) for estimating coastal property values, but they are not easily exchanged. Rather, a full suite of valuation techniques is required to quantify the economic value of goods and services provided by a naturally functioning coastal ecosystem. By using a range of methods for the same site, the so-called "total economic value" of a given coastal ecosystem can thus be estimated (Freeman 1993).

- **Avoided Cost** (AC): services allow society to avoid costs that would have been incurred in the absence of those services; flood control provided by barrier islands avoids property damages along the coast.
- **Replacement Cost** (RC): services could be replaced with man-made systems; nutrient cycling waste treatment can be replaced with costly treatment systems.
- **Factor Income** (FI): services provide for the enhancement of incomes;

water quality improvements increase commercial fisheries catch and incomes of fishermen.

- **Travel Cost** (TC): service demand may require travel, whose costs can reflect the implied value of the service; recreation areas attract distant visitors whose value placed on that area must be at least what they were willing to pay to travel to it.
- **Hedonic Pricing** (HP): service demand may be reflected in the prices people will pay for associated goods: For example, housing prices along the coastline tend to exceed the prices of inland homes.
- **Marginal Product Estimation** (MP): Service demand is generated in a dynamic modeling environment using production function (i.e., Cobb-Douglas) to estimate value of output in response to corresponding material input.
- **Contingent Valuation** (CV): service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; people would be willing to pay for increased preservation of beaches and shoreline.
- **Group Valuation** (GV): This approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from *open public debate.*

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Figure 2 depicts a model based on the idea of functional diversity, linking different ecosystem structures and processes with the output of specific goods and services, which can then be assigned monetary values using the range of valuation techniques described above.

Here, key linkages are made between the diverse structures and processes associated with the coastal zone, the landscape and habitat features that created them, and the goods and services that result. Once delineated, economic values for these goods and services can then be rationally assessed by measuring the diverse set of human preferences for them. In economic terms, the natural assets of the coastal zone can thus yield direct (fishing) and indirect (nutrient cycling) use values as well as non-use (preservation) values of the coastal system. Once accounted for, these values can then be aggregated to estimate the total value of the entire system (Anderson and Bishop 1986).

In principle, a global picture of the potential economic value associated with the coastal zone can be built up via the aggregation of a number of existing valuation studies. For example, in a preliminary estimate of the total economic value of ecosystem services provided by global systems, Costanza *et al.* (1997) showed that while the coastal zone

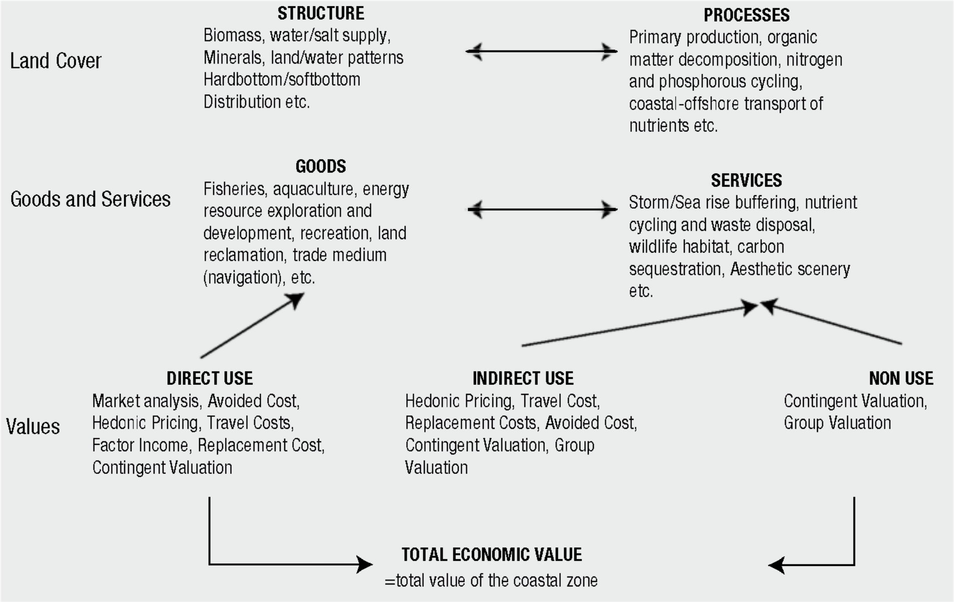

Figure 2: Total economic value of coastal zone functions, goods and services (Adapted from Turner 2000)

covers only 8% of the world's surface, the goods and services provided by it are responsible for approximately 43% of the estimated total value of global ecosystem services: US$ 12.6 Trillion in 1997 dollars. While controversial (Pearce 1998; Pimm 1997), this preliminary study made it abundantly clear that coastal ecosystem services do provide an important portion of the total contribution to human welfare on this planet. Furthermore, it demonstrated the need for additional research and indicated the fact that coastal areas are among the most in need of additional study (Costanza 2000).

On a smaller scale, such 'synthesis' studies often form the bedrock of practical policy analysis because only rarely can policy analysts or managers afford the luxury of designing and implementing an original study for every given ecosystem (Desvouges *et al.* 1998). Instead, we must often rely on the limited information that can be gleaned from past empirical studies that are often quite limited or even contradictory (Desvousges *et al.* 1992; Smith 1992). Primary valuation research, while being a 'first best' strategy, is also very expensive and time consuming. Thus, secondary analysis of the valuation literature is a 'second best' strategy that can nevertheless yield very important information in many scientific and management contexts (Rosenberger and Loomis 2000). When analyzed carefully, information from past studies published in the literature can form a meaningful basis for coastal zone policy and management (Beatley *et al.* 2002; French 1997). In the final section of this paper, we demonstrate our integrative approach to ecosystem service valuation by providing a brief review of case studies drawn from the literature.

4. RESULTS: EXAMPLES FROM THE LITERATURE 1978 TO 2002

Empirical valuation data for coastal ecosystems often appears scattered throughout the scientific literature and is uneven in quality. Despite this unevenness, below we present a brief review of existing valuation literature in order to provide useful insights for further research in the area. Such an exercise provides scientists and coastal managers alike with a sense of where the science of coastal ecosystem valuation has come from, and where it might go in the future. To accomplish this goal, below we have synthesized peer-reviewed economic data on coastal ecosystems depicted above in section 3, Table 1 and delineated a few key examples from the literature for extended discussion. In so doing, we hope to elucidate major findings and gaps in the literature.

All information presented below was obtained from studies that were published between 1978 and 2002. They deal *explicitly* with market and non-market coastal ecosystem goods and services measured throughout the world. To maintain consistency in data quality and findings, only peer-reviewed journal articles were included in this review. The literature search involved an intensive review of databases on the World Wide Web available at the University of Maryland. In total, twelve academic data bases were searched: *Academic Search Premier, ArticleFirst, Business Source Premier, ERIC, ISI Web of Science, JSTOR, OCLC Union Lists of Periodicals, PapersFirst, Proceedings First, USM Authority Database, World Almanac, and WorldCat.* Several keywords – economic value, economics, valuation, management, coastal, wetland, estuary, mangrove, ecosystem goods, and ecosystem service – were combined in various patterns to elicit studies that might be relevant to coastal ecosystem valuation. This search yielded fifty-one citations. Each citation was then located and reviewed by the authors. Twenty-eight citations (55%) were rejected because they were not peer-reviewed or did not explicitly address the economic valuation of coastal ecosystem goods and services.

The literature review yielded a total of twenty-three studies for further analysis and discussion (See Appendix). Results from these studies were then sorted by ecosystem good and service addressed, methodology and empirical data. On this basis, each study was classified as measuring an ecosystem good, service or any combination thereof (several studies report data for more than one good or service). Selected valuation estimates for coastal goods or services are reported in detail below in sections 5.1 and 5.2. The results from each study are reported in their original monetary metric.

5. ECOSYSTEM GOODS

Our review of the literature reveals that coastal ecosystems are among the most productive in the world today, rivaling even tropical rainforests in terms of their overall productivity of materials and goods used by humans (Barbier 1993; Primavera 1991; Spurgeon 1992). Many coastal regions are exploited through market activities that directly support humans – e.g., fishing, hunting, fuelwood and woodchip extraction, harvesting ornamental materials, and the extraction of medical resources.

5.1 Food

Coastal systems generate a variety of seafood products such as fish, mussels, crustaceans, sea cucumbers and seaweeds (Moberg and Folke 1999; Ronnback 1999). These products are vital to subsistence economies and provide a commercial base to local and national economies. For instance, fish and shrimp rank second in the value of export commodities for Bangladesh, and this represents 7% of the total export earnings and contributes 4.7% to GDP (Deb 1998). Given this level of economic productivity, it is perhaps not surprising that overfishing and intensive aquaculture have caused serious ecological and social problems in coastal regions (Jackson *et al.* 2001; Primavera 1991; 1997).

Valuation studies of food directly or indirectly supplied by coastal systems have predominantly focused on the economic value of fishery products (Barbier 2000; Batie and Wilson 1978; Bennett and Reynolds 1993; Buerger and Kahn 1989; Deb 1998; Farber and Costanza 1987; Gilbert and Janssen 1998; Kaoru *et al.* 1995; Lynne *et al.* 1981; Rivas and Cendrero 1991; Ronnback 1999; Ruitenbeek 1994; Sathirathai and Barbier 2001). Most often, the market price of seafood products is used as a proxy when calculating the value of ecosystem goods provided by coastal systems. For example, the annual market value of seafood supported by mangroves has been calculated to range from US$750 to $16,750 (in 1999 dollar) per hectare (Ronnback 1999).

Lynne *et al.* (1981) suggested that the value of the coastal marsh in southern Florida could be modeled by assuming that seafood harvest is a direct function of salt-marsh area. The authors then derived the economic value of a specified change in marsh area through the marginal productivity of fishery harvest. For the blue crab fishery in western Florida salt marshes, a marginal productivity of 2.3 1b per year for each acre of marshland was obtained. By linking the market price of harvested blue crab to this estimate, the authors were able to estimate of the total present value of a marsh acre in human food (blue crab) production at $3.00 for each acre (with a 10% capitalization rate).

5.2 Raw Materials

Raw materials refer to renewable biotic resources such as wood and fibers for building, biochemicals or biodynamic compounds for all kinds of industrial purposes (DeGroot *et al.* 2002). According to Costanza *et al.* (1997), for example, the net value of raw materials provided by coastal systems worldwide is approximately $4/ha/year (1994 dollars). Surprisingly, however, when compared to the number of valuation studies that measure the market value of seafood products, fewer studies on raw materials were gleaned from the literature. From the literature, we were able to identify three empirical studies dealing with the raw material productivity of mangrove areas (Bennett and Reynolds 1993; Ruitenbeek 1994; Sathirathai and Barbier 2001). Here, local direct uses derived from mangrove areas were valued by determining the net income generated from harvesting timber, fuel wood, and other wood products as well as nonwood resources, such as birds and crabs.

For example, by conducting household interviews with 44 households in the Tha Po Village, Southern Thailand, Sathirathai and Barbier (2001) estimated the average annual net income per household by collecting data on the amount of raw materials (e.g., wood for fishing gear) gathered by the household. The direct use value of mangrove resources was assumed to be equivalent to the net income generated from the forests in terms of various wood and nonwood products. Based on the estimated net income from all mangrove products (fuelwood, honey, wood for fishing gear, molluscs etc.) the authors report the mean annual value per household at around $924 (1996 dollars). In another similar study, Bennett and Reynolds (1993) estimated the value of timber products provided by Sarawak mangroves to be worth $123,217.

5.3 Genetic, Medical and Ornamental

Besides food and raw materials, at least three other types of ecosystem goods are provided by coastal systems – genetic resources, medical resources and ornamental resources. While we were unable to locate reliable economic estimates for these products in the peer-reviewed literature, we were able to identify studies that document their social significance and potential economic value. For example, the coastal marine environment (e.g., reefs) has been shown to be an exceptional reservoir of bioactive natural products, many of which exhibit structural features not found in terrestrial natural products (Carte 1996). The pharmaceutical industry has discovered several potentially useful substances among the seaweeds, sponges, molluscs, corals, sea cucumbers and sea anemones of the reefs (Carte 1996; Moberg and Folke 1999). Furthermore, many coastal products are collected not only as food but also to sell as jewellery and souvenirs. Mother-of-pearl shells, giant clams, and red coral are collected and distributed as part of the worldwide curio trade (Craik *et al.* 1990). The marine aquarium market is now a multi million dollar per year industry trading in live reef-dwelling fishes that are collected and shipped live from coral reef communities (Moberg and Folke 1999).

6. ECOSYSTEM SERVICES

In addition to marketable goods and products, our analysis of the literature reveals that landscape features and habitats in the coastal zone also provide critical natural services that contribute to human welfare, and thus have significant economic value (Farber and Costanza 1987). As the aforementioned pattern of data in Table 1 suggests, much of what people value in the coastal zone – natural amenities (open spaces, attractive views), good beaches for recreation, high levels of water quality, protection from storm surges, and waste assimilation/nutrient cycling – are provided by coastal systems. Below, we review a select published group of these economic value estimates.

6.1 Recreation and Nutrient Regulation

Stretches of beach, rocky cliffs, estuarine and coastal marine waterways, and coral reefs provide numerous recreational and scenic opportunities for humans. Boating, fishing, swimming, walking, beachcombing, scuba diving, and sunbathing are among the numerous leisure activities that people enjoy worldwide and thus represent significant economic value (Farber 1988; Kawabe and Oka 1996; King 1995; Morgan and Owens 2001; Ofiara and Brown 1999). Both travel cost (TC) and Contingent Valuation (CV) methods are commonly used to estimate this value. For example, the Chesapeake Bay estuary on the eastern seaboard of the United States has been the focus of an impressive amount of research on nonmarket recreational values associated with coastal systems. When attempting to estimate the monetary worth of water quality improvements in Chesapeake bay, Bocksteal *et al.* (1989) focused on recreational benefits because it was assumed that most of the increase in well-being associated with such improvements would accrue to recreationists (p.2). The authors estimated the average increases in economic value for beach use, boating, swimming, and fishing with a 20% reduction in total nitrogen and phosphorus introduced into the estuary. Using a combination of CV and TC methods, the annual aggregate willingness to pay for a moderate improvement in the Chesapeake Bay's water quality was estimated to be in the range of $10 to $100 million in 1984 dollars (Bocksteal *et al.* 1989). In a similar study, Kawabe and Oka (1996) used TC to estimate the aggregate recreational benefit (viewing the bay, clam digging, bathing, sailing, bathing, snorkeling and surfing) from improving organic contamination of Tokyo Bay by nitrogen at 53.2 billion yen. Using the CV method, the authors also estimated the aggregate value of improving chemical oxygen demand to reduce the reddish-brown color of the bay at 458.3 billion yen (Kawabe and Oka 1996).

As discussed previously in section 3, in addition to habitat services, humans can value the landscape features of the coastline directly. For example King (1995) conducted a CV study to estimate the value of beach quality in Southeast England. The main survey was conducted in August 1993 in the town of Eastbourne off the Dover Straits during peak tourist season (King 1995). By asking respondents to state the maximum amount that they would be willing to pay for a daily entrance fee to use the seafront and beaches, the author estimated the mean WTP per visitor at £1.78. Using existing information on the total annual number of visitor days, the aggregate annual value of Eastbourne's beaches and seafront were calculated to be approximately £4.5 million.

6.2 Aesthetic Information

Open space, proximity to clean water, and scenic vistas are often cited as a primary attractor of residents who own property and live within the coastal fringe (Beach 2002). Hedonic pricing (HP) techniques have thus been used to show that the price of coastal housing units vary with respect to characteristics such as ambient environmental quality (e.g., proximity to shoreline, water quality) because buyers will bid up the price of units with more of a desirable attribute (Johnston *et al.* 2001). For example, Leggett and Bockstael (2000) use hedonic techniques to show that water quality has a significant effect on property values along the Chesapeake Bay, USA. The authors use a measure of water quality – fecal coliform bacteria counts – that has serious human health implications and for which detailed, spatially explicit information from monitoring is available. The data used in this hedonic analysis consists of sales of waterfront property on the western shore of the Chesapeake Bay that occurred between 1993 and 1997 (Leggett and Bockstael 2000). The authors consider the effect of a hypothetical localized improvement in observed fecal coliform counts – 100 counts per 100ml – on a set of 41 residential parcels. The projected increase in property values due to the hypothetical reduction totals approximately $230,000. Extending the analysis to calculate an upper bound benefit for

494 properties, the authors estimate the benefits of improving water quality at all sites at \$12.145 million (Leggett and Bockstael 2000, p.142).

6.3 Disturbance Prevention

A critically important service provided by coastal landscapes such as barrier islands, inland wetlands areas, beaches and tidal plains is disturbance prevention. Significant property damages have been attributed to flooding from tidal surges and rainfall as well as wind damage associated with major storm events (Farber 1987; Farber and Costanza 1987). For example, Farber (1987) has described an "Avoided Cost" method for measuring the hurricane protection value of wetlands against wind damage to property in coastal Louisiana, USA. Using historical probabilities for storms and wind damage estimates in Louisiana, an expected wind damage function was derived and from this, expected reductions in wind damage from the loss of 1 mile of wetlands were estimated. Based on 1983 US dollars, the expected incremental annual damaged from a loss of 1 mile of wetlands along the Louisiana coastline was \$69,857 which, when extrapolated to a per-acre estimate, amounts to \$.44 per acre (Farber 1987).

In another study, Parsons and Powell (2001) measure the cost of land and capital loss, especially in housing, associated with beach retreat in the State of Delaware, USA. The costs associated with beach retreat are grouped into four primary categories: land loss, capital loss (structures) proximity loss, and transition loss (Parsons and Powell 2001). As the vast majority of developed land in coastal Delaware is residential housing, the authors focus on the residential land and housing market as a baseline estimate of the cost of beach retreat. Using a hedonic regression analysis, the authors estimate the cost of beach retreat in Delaware over a 50 year period to be about \$291 million in yr 2000 dollars.

6.4 Habitat and Nursery Functions

As mentioned previously in this paper, the coastal zone is one of the most productive ecological habitats in the world (Gosselink *et al.* 1974; Turner *et al.* 1996). Eelgrass, salt marsh and intertidal mud flats all provide a variety of services to the public associated with their nursery and habitat functions. As we have already reported, improvements in the ecological integrity of these habitats may ultimately lead to measurable increases in the production of market goods such as fish, birds and wood products. In other cases, however, ecological productivity itself can represent a unique class of values not captured by traditional market-based valuation methods. Instead, these values represent an increase in the production of higher trophic levels brought about by the increased availability of habitat (Gosselink *et al.* 1974; Turner *et al.* 1996). Here, it is critical to realize that one may not, in general, add productivity value estimates to use values estimated using other market-related methodologies (e.g., hedonic and travel cost) because to do so would risk double counting some aspects of value, or measuring the same benefits twice (Desvouges *et al.* 1992, 1998).

In an example of coastal wetland productivity analysis, Johnston *et al.* (2002) use a simulation model based on biological functions that contribute to the overall productivity of the food web in the Peconic Estuary System (PES) in Suffolk County NY, USA. Based on habitat values for fin and shellfish, birds and waterfowl, an average annual abundance per unit area of wetland habitat in the PES is estimated by summing all relevant food web values and habitat values for a year (Johnston *et al.* 2002). The value of fish and shellfish is based on commercial harvest values. The marginal value of bird species usage of the habitat is based on the benefits human receive from viewing or hunting waterfowl. Using these values as input data, the simulation model result in annual marginal asset values for three wetland types: Eelgrass ($1,065 per acre/year); Saltmarsh ($338 per acre/year); and Inter-tidal mud flat ($67 per acre/year).

In an earlier study, Farber and Costanza (1987) estimated the marginal productivity of a coastal system in Terrebonne Parish, Louisiana, USA by attributing commercial values for several species to the net biomass, habitat, and waste treatment of the wetland ecosystem (Farber and Costanza 1987). Arguing that the annual harvest from an ecosystem is a function of the level of environmental quality, the authors chose to focus on the commercial harvest data for five different native species – shrimp, blue crab, oyster, menhaden, and muskrat – to estimate the marginal productivity of wetlands. The annual economic value (marginal product) of each species was estimated in 1983 dollars: shrimp $10.86/acre; blue crab $.67/acre; oyster $8.04/acre; menhaden $5.80/acre; and muskrat pelts $12.09/acre. Taken together, the total value marginal productivity of wetlands in Terrebonne Parish, Louisiana was estimated at $37.46 per acre.

DISCUSSION

Ecosystem goods and services form a pivotal conceptual link between human and ecological systems. In this paper, we have shown how ecosystem goods and services are critical to the functioning of coastal systems and that they also contribute significantly to human welfare, representing a significant portion of the total economic value of the coastal environment. Using an integrated framework developed for the assessment of ecosystem goods and services within the coastal zone, we have considered how ecological structures and processes, land use decisions, and human values interact in the coastal zone. The concept of ecosystem goods and services has thus allowed us to analyze how human beings as welfare-maximizing agents actively translate basic ecological structures and processes into value-laden entities.

The literature reviewed here demonstrates both the opportunities and the challenges inherent in estimating the economic value of coastal ecosystem goods and services. As the pattern of data in Table 1 suggests, one of the major insights from our analysis is the discrepancy between the ecosystem goods and services that have been documented in the published valuation literature and those that could potentially contribute significantly to human welfare, both directly and indirectly. Accounting for these missing economic values represents a significant challenge for scientists, planners and decision makers involved in coastal zone research and management.

The diversity of studies reviewed here suggests that methodological guidelines and standards are still evolving. However, it is evident that within specific contexts, defensible dollar estimates can be obtained and thereby add to the information base for coastal management and decision making. These estimates may require considerable creative research and have substantial uncertainties. Yet, despite these limitations, the available data suggest that humans do indeed attach substantial positive economic values to the many market and non-market goods and services coastal systems provide.

Through laws and rules, land use management and policy decisions, individuals and social groups ultimately will make tradeoffs between these values as they continue to live, work and play in the coastal zone. In turn, these land use decisions will directly modify the structures and processes of the coastal zone through engineering and construction and/or indirectly by modifying the physical, biological and chemical processes of the natural system. Resource managers and ecologists should therefore be aware that non-use values have been shown to comprise a sizable portion of total economic value associated with coastal ecosystems. One important conclusion that follows is that if such values are left out of policy analysis, resulting policy decisions will tend to overestimate the role of use values, and underestimate the role of non-use values. Without efforts to quantify the non-use benefits associated with freshwater ecosystem goods and services, policy and managerial decisions could potentially be skewed in favor of environmentally degrading practices by neglecting the diffuse social interests that benefit from the many non-use oriented characteristics of such systems.

The science of ecology must play a crucial role in bringing concepts like *ecosystem goods and services* to the foreground of the valuation debate (Costanza *et al.* 1997; Daily 1997; Wilson and Carpenter 1999). As we have shown, assigning economic values to landscape features and habitat functions of coastal ecosystems requires a full understanding of the nature of the natural systems upon which they rest. Ecosystem structures and processes are influenced by long-term, large-scale biogeophysical drivers (i.e., tectonic pressures, global weather patterns) which in turn create the necessary conditions for providing the ecosystem goods and services people value. Ecological information must therefore be thoroughly integrated into an integrative conceptual framework before a meaningful assessment of economic value can be made. This is a formidable challenge, but we believe that the landscape classification system presented in section 3 of this paper provides a critical first step.

We conclude with the observation that most valuation studies to date have been performed for relatively few coastal ecosystem goods and services at a limited number of sites in the world. Hence, our ability to generalize from studies presented in this review is limited (Desvouges *et al.* 1998). Nevertheless, the results presented here do provide valuable insights into the challenges and limitations of ecosystem service valuation as it is currently being practiced. The experiences summarized here should be useful to ecologists, managers, and social scientists as they collaborate to estimate the total value of coastal ecosystem goods and services.

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REFERENCES

Ableson, P. 1979. *Cost-Benefit Analysis and Environmental Problems.* London. Saxon House.

Anderson, G.D. and Bishop, R.C. 1986. The valuation problem. In D.W. Bromley (ed.) *Natural resource economics: policy problems and contemporary analysis,* 89–137. Boston, MA. Liuwer Nijoff Publishing.

Barbier, E.B. 1993. Sustainable use of wetlands – valuing tropical wetland benefits – economic methodologies and applications. *Geographical Journal* **159**, 22–32.

Barbier, E.B. 2000. Valuing the environment as input: review of applications to mangrove-fishery linkages. *Ecological Economics* **35**, 47–61.

Batie, S.S. and Wilson, J.R. 1978. Economic values attributable to Virginia's coastal wetlands as inputs in oyster production. *Southern Journal of Agricultural Economics* July 1978, 111–118.

Beach, D. 2002. Coastal Sprawl: the effects of urban design on aquatic ecosystems in the United States. Arlington, VA. Pew Oceans Commission.

Beatley, T., Brower, D.J., and Schwab, A.K. 2002. *An Introduction to Coastal Zone Management.* Washington, D.C. Island Press.

Bennett, E.L. and Reynolds, C.J. 1993. The value of a mangrove area in Sarawak. *Biodiversity and Conservation* **2**, 359–375.

Bingham, G., Bishop, R., Brody, M., Bromley, D., Clark, E., Cooper, W., Costanza, R., Hale, T., Hayden, G., Kellert, S., Norgaard, R., Norton, B., Payne, J., Russell, C., and Suter, G. 1995. Issues in ecosystem valuation: improving information for decision making. *Ecological Economics* **14**, 73–90.

Bishop, R.C., Champ, P.A., Brown, T.C., and McCollum, D.W. 1997. Measuring Non-Use Values: Theory and Empirical Applications. In R.J. Kopp, W.W. Pommerehne, and N. Schwarz. (eds) *Determining the Value of Non-Marketed Goods,* 59–81. Boston. Kluwer Academic Publishers.

Bocksteal, N.E., McConnell, K.E., and Strand, I.E. 1989. Measuring the benefits of improvements in water quality: The Chesapeake Bay. *Marine Resource Economics* **6**, 1–18.

Boumans, R.M.J., Costanza, R., Farley, J., Wilson, M.A., Rotmans, J., Villa, F., Portela, R., and Grasso, M. 2002. Modeling the dynamics of the integrated earth system and the value of global ecosystem services using the GUMBO model. *Ecological Economics* **41**, 529–560.

Buerger, R. and Kahn, J.R. 1989. New York value of Chesapeake striped bass. *Marine Resource Economics* **6**, 19–25.

Carte, B.K. 1996. Biomedical potential of marine natural products. *Bioscience* **46**, 271–286.

Cohen, J.F., Small, C., Mellinger, A., Gallup, J., and Sachs, J. 1997. Estimates of coastal populations. *Science* **278**, 1211–1212.

Costanza, R. 2000. The ecological, economic and social importance of the oceans. In C.R.C. Sheppard (ed.) *Seas at the Millennium: An Environmental Evaluation, vol. III. Global Issues and Processes,* 393–403. New York. Pergamon.

Costanza, R., D'Arge, R., DeGroot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature, London* **387**, 253–260.

Costanza, R. and Folke, C. 1997. Valuing ecosystem services with efficiency, fairness, and sustainability as goals. In G.C. Daily (ed.) *Nature's Services,* 49–68. Washington, D.C. Island Press.

Craik, W., Kenchington, R., and Kelleher, G. 1990. Coral reef management. In Z. Dubinsky (ed.) *Ecosystems of the World 25: Coral Reefs,* 453–467. New York. Elsevier.

Daily, G.C. 1997. *Nature's Services: Societal Dependence on Natural Ecosystems.* Washington, D.C. Island Press.

Deb, A.K. 1998. Fake blue revolution: environmental and socio-economic impacts of shrimp culture in the coastal areas of Bangladesh. *Ocean and Coastal Management* **41**, 63–88.

DeGroot, R., Wilson, M.A., and Boumans, R.M.J. 2002. A typology for the classification, description, and valuation of ecosystem functions, goods and services. *Ecological Economics* **41**, 393–408.

Desvouges, W.H., Johnson, F.R., and Banzhaf, H.S. 1998. *Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method,* W.E. Oates and H. Folmer (eds). Northampton MA. Edward Elgar.

Desvousges, W.H., Naughton, M.C., and Parsons, G.R. 1992. Benefit transfer – conceptual problems in estimating water-quality benefits using existing studies. *Water Resources Research* **28**, 675–683.

Di Gregorio, A. and Jansen, L. 2000. *Land Cover Classification System (LCCS): Classification Concepts and User Manual.* Rome. Food and Agricultural Organization of the United Nations.

Farber, S. 1987. The value of coastal wetlands for the protection of property against hurricane wind damage. *Journal of Environmental Economics and Management* **14**, 143–151.

Farber, S. 1988. The value of coastal wetlands for recreation – an application of travel cost and contingent valuation methodologies. *Journal of Environmental Management* **26**, 299–312.

Farber, S. and Costanza, R. 1987. The economic value of wetlands systems. *Journal of Environmental Management* **24**, 41–51.

Farber, S., Costanza, R., and Wilson, M.A. 2002. Economic and ecological concepts for Valuing Ecosystem Services. *Ecological Economics* **41**, 375–392.

Freeman, M. 1993. *The Measurement of Environmental and Resource Values.* Washington, D.C. Resources for the Future.

French, P.W. 1997. *Coastal and Estuarine Management.* New York. Routledge.

Gilbert, A.J. and Janssen, R. 1998. Use of environmental functions to communicate the values of a mangrove ecosystem under different management regimes. *Ecological Economics* **25**, 323–346.

Gosselink, J.G., Odum, E.G., and Pope, R.M. 1974. *The value of the tidal marsh.* Baton Rouge. Center for Wetland Resources, Louisiana State University.

Goulder, L.H. and Kennedy, D. 1997. Valuing ecosystem services: philosophical bases and empirical methods. In G.C. Daily (ed.) *Nature's Services: Societal Dependence on Natural Ecosystems,* 23–48. Washington, D.C. Island Press.

Hanley, N. and Spash, C. 1993. *Cost-Benefit Analysis and the Environment.* Cornwall. Edward Elgar Publishing.

Hinrichsen, D. 1998. *Coastal Waters of The World: Trends, Threats, and Strategies.* Washington, D.C. Island Press.

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., and Warner, R.R. 2001. Historical overfishing and the recent collapse of coastal ecosystems. *Science* **293**, 629–638.

Johnston, R.J., Grigalunas, T.A., Opaluch, J.J., Mazzotta, M., and Diamantedes, J. 2002. Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System study. *Coastal Management* **30**, 47–65.

Johnston, R.J., Opaluch, J.J., Grigalunas, T.A., and Mazzotta, M.J. 2001. Estimating amenity benefits of coastal farmland. *Growth and Change* **32**, 305–325.

Kaoru, Y., Smith, V.K., and Liu, J.L. 1995. Using random utility-models to estimate the recreational value of estuarine resources. *American Journal of Agricultural Economics* **77**, 141–151.

Kawabe, M. and Oka, T. 1996. Benefit from improvement of organic contamination of Tokyo Bay. *Marine Pollution Bulletin* **32**, 788–793.

King, O.H. 1995. Estimating the value of marine resources: a marine recreation case. *Ocean & Coastal Management* **27**, 129–141.

Kneese, A. 1984. *Measuring the Benefits of Clean Air and Water.* Washington, D.C., Resources for the Future.

Leggett, C.G. and Bockstael, N.E. 2000. Evidence on the effects of water quality on residential land prices. *Journal of Environmental Economics and Management* **39**, 121–144.

Lynne, G.D., Conroy, P., and Prochaska, F.J. 1981. Economic valuation of marsh areas for marine production processes. *Journal of Environmental Economics and Management* **8**, 175–186.

Moberg, F. and Folke, C. 1999. Ecological goods and services of coral reef ecosystems. *Ecological Economics* **29**, 215–233.

Morgan, C. and Owens, N. 2001. Benefits of water quality policies: the Chesapeake Bay. *Ecological Economics* **3**, 271–284.

Ofiara, D.D. and Brown, B. 1999. Assessment of economic losses to recreational activities from 1988 marine pollution events and assessment of economic losses from long-term contamination of fish within the New York Bight to New Jersey. *Marine Pollution Bulletin* **38**, 990–1004.

Parsons, G.R. and Powell, M. 2001. Measuring the cost of beach retreat. *Coastal Management* **29**, 91–103.

Pearce, D. 1998. Auditing the earth. *Environment* **40**, 23–28.

Pimm, S.L. 1997. The value of everything. *Nature,* London **387**, 231–232.

Primavera, J.H. 1991. Intensive prawn farming in the Philippines – Ecological, social, and economic-implications. *Ambio* **20**, 28–33.

Primavera, J.H. 1997. Socio-economic impacts of shrimp culture. *Aquaculture Research* **2**, 815–827.

Rivas, V. and Cendrero, A. 1991. Use of natural and artificial accretion on the north coast of Spain – historical trends and assessment of some environmental and economic consequences. *Journal of Coastal Research* **7**, 491–507.

Ronnback, P. 1999. The ecological basis for economic value of seafood production supported by mangrove ecosystems. *Ecological Economics* **29**, 235–252.

Rosenberger, R.S. and Loomis, J.B. 2000. Using meta-analysis for benefit transfer: In-sample convergent validity tests of an outdoor recreaton database. *Water Resources Research* **36**, 1097–1107.

Ruitenbeek, H.J. 1994. Modeling economy ecology linkages in mangroves – economic evidence for promoting conservation in Bintuni Bay, Indonesia. *Ecological Economics* **10**, 233–247.

Sathirathai, S. and Barbier, E.B. 2001. Valuing mangrove conservation in southern Thailand. *Contemporary Economic Policy* **19**, 109–122.

Smith, V.K. 1992. On separating defensible benefit transfers from 'smoke and mirrors'. *Water Resources Research* **28**, 685–694.

Spurgeon, J.P.G. 1992. The economic valuation of coral reefs. *Marine Pollution Bulletin* **24**, 529–536.

Townend, I. 2002. Marine Science for strategic planning and management: the requirement for estuaries. *Marine Policy* **26**, 209–219.

Turner, R.K. 2000. Integrating natural and socio-economic science in coastal management. *Journal of Marine Systems* **2**, 447–460.

Turner, R.K., Subak, S., and Adger, W.N. 1996. Pressures, trends and impacts in coastal zones: interactions between socioeconomic and natural systems. *Environmental Management* **20**, 159–173.

Vitousek, P.M., Mooney, H.A., Lubchenco, J., and Melillo, J.M. 1997. Human domination of earth's ecosystems. *Science* **227**, 494–499.

Wilson, M.A. and Carpenter, S.R. 1999. Economic valuation of freshwater ecosystem services in the United States 1971–1997. *Ecological Applications* **9**, 772–783.

APPENDIX: COASTAL SERVICES VALUATION BIBLIOGRAPHY

1. BARBIER, E.B., Valuing the environment as input: review of applications to mangrove-fishery linkages. *Ecological Economics,* 2000. 35(1): pp. 47–61.
2. BATIE, S.S. and WILSON, J.R., Economic Values Attributable to Virginia's Coastal Wetlands as Inputs in Oyster Production. *Southern Journal of Agricultural Economics,* 1978. July: pp. 111–118.
3. BENNETT, E.L. and REYNOLDS, C.J., The Value of a Mangrove Area in Sarawak. *Biodiversity and Conservation,* 1993. 2(4): pp. 359–375.
4. BOCKSTEAL, N.E., McCONNELL, K.E. and STRAND, I.E., Measuring the Benefits of Improvements in Water Quality: The Chesapeake Bay. *Marine Resource Economics,* 1989. 6: pp. 1–18.
5. BUERGER, R. and KAHN, J.R., New York Value of Chesapeake Striped Bass. *Marine Resource Economics,* 1989. 6: pp. 19–25.
6. DEB, A.K., Fake blue revolution: environmental and socio-economic impacts of shrimp culture in the coastal areas of Bangladesh. *Ocean and Coastal Management,* 1998. 41: pp. 63–88.
7. FARBER, S., The value of coastal wetlands for the protection of property against hurricane wind damage. *Journal of Environmental Economics and Management,* 1987. 14(2): pp. 143–151.
8. FARBER, S., The Value of Coastal Wetlands for Recreation – an Application of Travel Cost and Contingent Valuation Methodologies. *Journal of Environmental Management,* 1988. 26(4): pp. 299–312.
9. FARBER, S. and COSTANZA, R., The Economic Value of Wetlands Systems. *Journal of Environmental Management,* 1987. 24(1): pp. 41–51.
10. GILBERT, A.J. and JANSSEN, R., Use of environmental functions to communicate the values of a mangrove ecosystem under different management regimes. *Ecological Economics,* 1998. 25(3): pp. 323–346.
11. JOHNSTON, R.J., GRIGALUNAS, T.A., OPALUCH, J.J., MAZZOTTA, M. and DIAMANTEDES, J. Valuing estuarine resource services using economic and ecological models: the Peconic Estuary System study. *Coastal Management,* 2002. 30(1): pp. 47–65.
12. KAORU, Y., SMITH, V.K., and LIU, J.L., Using Random Utility-Models to Estimate the Recreational Value of Estuarine Resources. *American Journal of Agricultural Economics,* 1995. 77(1): pp. 141–151.
13. KAWABE, M. and OKA, T., Benefit from improvement of organic contamination of Tokyo Bay. *Marine Pollution Bulletin,* 1996. 32(11): pp. 788–793.
14. KING, O.H., Estimating the value of marine resources: a marine recreation case. *Ocean and Coastal Management,* 1995. 27(1–2): pp. 129–141.
15. LEGGETT, C.G. and BOCKSTAEL, N.E., Evidence on the Effects of Water Quality on Residential Land Prices. *Journal of Environmental Economics and Management,* 2000. 39: pp. 121–144.
16. LYNNE, G.D., CONROY, P., and PROCHASKA, F.J., Economic Valuation

of Marsh Areas for Marine Production Processes. *Journal of Environmental Economics and Management,* 1981. 8: pp. 175–186.

17. OFIARA, D.D. and BROWN, B., Assessment of Economic Losses to Recreational Activities from 1988 Marine Pollution Events and Assessment of Economic Losses from Long-Term Contamination of Fish within the New York Bight to New Jersey. *Marine Pollution Bulletin,* 1999. 38(11): pp. 990–1004.
18. PARSONS, G.R. and POWELL, M., Measuring the Cost of Beach Retreat. *Coastal Management,* 2001. 29: pp. 91–103.
19. RIVAS, V. and CENDRERO, A., Use of Natural and Artificial Accretion on the North Coast of Spain – Historical Trends and Assessment of Some Environmental and Economic Consequences. *Journal of Coastal Research,* 1991. 7(2): pp. 491–507.
20. RONNBACK, P., The ecological basis for economic value of seafood production supported by mangrove ecosystems. *Ecological Economics,* 1999. 29(2): pp. 235–252.
21. SATHIRATHAI, S. and BARBIER, E.B., Valuing mangrove conservation in southern Thailand. *Contemporary Economic Policy,* 2001. 19(2): pp. 109–122.
22. SMITH, V.K., PALMQUIST, R.B. and JAKUS, P., Combining Farrell Frontier and Hedonic Travel Cost Models for Valuing Estuarine Quality. *The Review of Economics and Statistics,* 1991. 73(4): pp. 694–699.
23. THIBODEAU, F.R. and OSTRO, B.D., An economic analysis of wetland protection. *Journal of Environmental Management,* 1981. 12: pp. 19–30.