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A Methodological Review of Net Benefit Evaluation for Marine Reserves

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Foreword

The idea for this paper arose out of discussions that began several years ago between Jim Broadus, at the Woods Hole Oceanographic Institution, and John Dixon, who was then at the East-West Center. Their idea was to survey the literature on marine reserve designations and management systems and to characterize the state-of-the-art in net benefit evaluation methodologies with an eye toward how these methods might usefully be applied to improve decisionmaking for marine reserves. This paper is intended to be a window to the relevant literature on marine reserve valuation, not a handbook on cost-benefit analysis or a collection of case studies. We summarize some general, but hopefully useful, conclusions from this and related literature to help policymakers think critically about marine reserve valuation issues and about specific cases. We welcome any comments, suggestions, or recommendations for improving the technical contents of the paper or its presentation.

We thank Sarah Repetto for able research assistance in the early phases of this work. We thank Scott Farrow, Di Jin, Bob Leeworthy, George Parsons, Mary Schumacher, and Andy Solow for helpful discussions and suggestions. We thank John Dixon of the World Bank's Environment Department for his encouragement as sponsor of this work.

We are indebted to Jim Broadus for initiating this project and for securing World Bank sponsorship. Jim was deeply interested in the application of economic methodologies to improve the management of ocean resources, and we dedicate this paper to his memory.

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1 Introduction

This report surveys and reviews methodological issues relating to the evaluation of net economic benefits associated with the creation and operation of marine reserves.[1]

As shown in Figure 1, the designation of areas of ocean space as marine reserves is not a new practice, but these designations have become more frequent within the last two decades. As the total number of reserves has grown, especially during the 1970s and 1980s, management theories and practices have advanced apace (WCMC 1994; CNPPA 1994; Polunin 1990; Foster and LeMay 1989; Salm and Clark 1984; Irland 1979). While economic theory generally is recognized as a powerful tool for aiding natural resource decisions, such as those involved in the designation and management of marine reserves, the number of applications of economic analysis to marine reserve decisionmaking is remarkably small.[2]

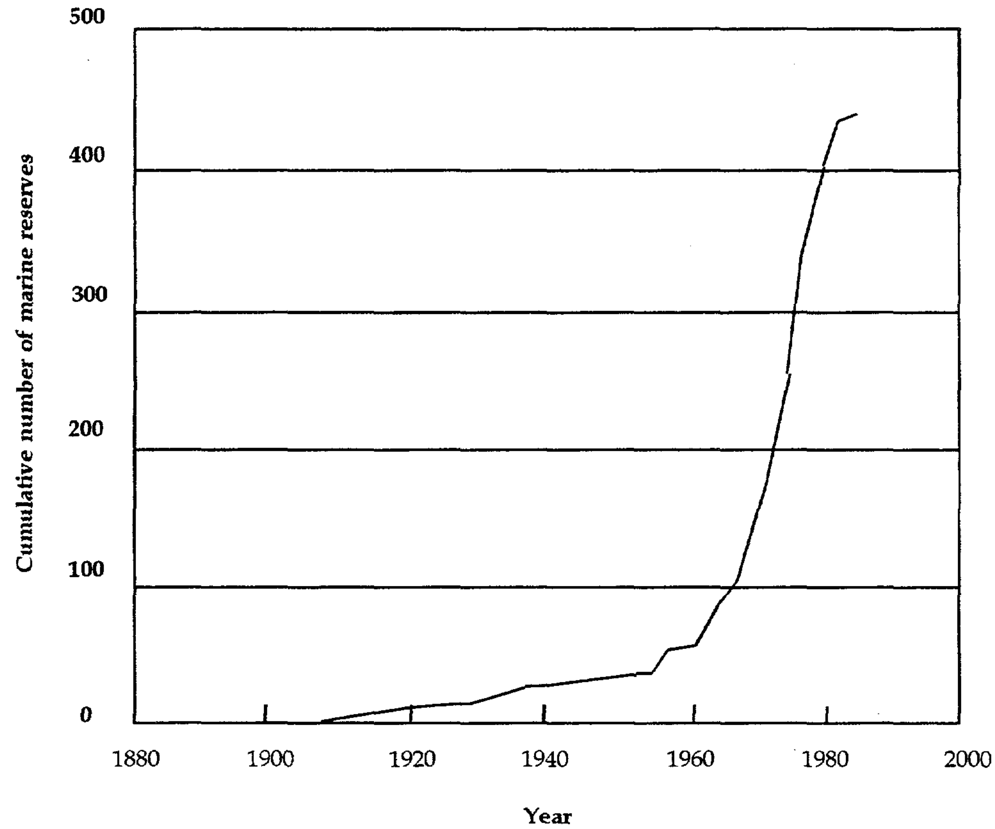
The creation and management of a marine reserve can be understood as a type of *social investment*. Like all investments, the establishment of a marine reserve may involve irreversible commitments, uncertainty about future net benefit flows, and issues of optimal timing (see generally Dixit and Pindyck 1994). A careful analysis of the flow of all relevant benefits and costs from investment in a marine reserve can improve the potential for achieving both efficient resource management and sustainable economic development.[3]

Marine reserves often have as one main focus the protection of rare ecosystems or fisheries and wildlife habitats, although this may not be the only reason[4] for their creation. Heavy industrial uses and other uses potentially destructive of wildlife or its habitats usually are restricted or prohibited within the confines of a marine reserve. Nonconsumptive uses, such as ecotourism and scuba diving, or certain kinds of recreational fishing may be promoted.

In many countries, there exists a positive empirical relationship between economic growth and leisure. As the world's economies have grown, tourism, as a leisure activity, has expanded worldwide. Tourism industries have grown apace with coastal and marine tourist visits, placing pressures on heretofore unspoiled environments in both developed and developing countries. For countries that seek to balance economic development with environmental protection, marine reserves can be an important natural resource management tool.

At a *general* level, the important economic issues associated with the creation and management of *both* land-based and marine reserves are identical. These issues involve the evaluation of nonmarket goods and opportunity costs, the potential for benefits transfer applications, resource pricing, issues of geographic scale and regulatory scope, among others. Further, policy evaluation questions, including the distribution of benefits and costs, are relevant to both types of reserves. As a result, studies of approaches to the evaluation of land-based reserves (e.g., Dixon and Sherman 1990) can be helpful in the selection and implemention of appropriate economic methodologies in marine settings.

Figure 1
Cumulative establishment of marine reserves worldwide



Source: adapted from Silva et al. (1986).

At a more *specific* level, analysts have suggested that marine reserves may differ from their land-based counterparts in ways that may be relevant to selecting and applying the most appropriate net benefit evaluation methodologies. The following are a few hypothetical reasons why marine reserves may differ from coastal or land-based reserves (these reasons are not mutually exclusive).

- *Human uses*: A marine reserve does not normally provide habitat for humans (Doeleman 1991). This characteristic is one piece of evidence that those individuals who actually use a marine reserve may have different tastes and socioeconomic characteristics (e.g., incomes, ages, education levels, etc.) than those who use land-based reserves.[5]

- *Nature of uses*: Because marine reserves tend to be more remote than coastal or land-based reserves, patterns of visitation may differ.[6] In particular, costs of travel to the reserve may be relatively steeper. Moreover, a significant portion of the benefits from reserve designation may derive from indirect uses (e.g., as refugia for stocks of marine fish and mammals) or from bequest or vicarious "nonuses."

- *Open access*: Both access to a reserve and the use of its resources are difficult to control, in particular because of problems in marking boundaries (Tisdell and Broadus 1989). This characteristic implies that monitoring and enforcement costs may be significantly greater for marine reserves than for land-based reserves.

- *Resource fugitivity*: Management of fisheries and wildlife, especially containment, may be difficult (Tisdell and Broadus 1989). Similarly, marine pollutant flows and effects are clearly different, and control or clean-up may be more difficult than on land.

- *Property or liability rights*: The rights to use ocean resources or liabilities for damage to ocean resources may differ from those on land. International legal institutions may conflict with domestic management priorities.

Recent developments in the field of environmental and natural resource economics have increased the potential either for more efficient or more cost-effective decisions with respect to the design, creation, and management of marine reserves (Barton 1994; Tisdell 1991; Doeleman 1991; Dixon and Sherman 1990). More progress is required, however, in accounting for the full range of economic benefits and costs associated with marine reserves and in understanding how investments in them are likely to lead to the greatest net benefits over time.

As an initial contribution to this end, we have conducted a survey and review of net benefits evaluation methodologies for marine reserves. Our survey and review has been organized as follows:

- Sources of benefits and costs, including:
  - financial accounting and market observable measures of benefits and costs;
  - nonmarket values, including indirect (travel cost) and direct (CVM) measures;
  - valuation of biological diversity;

- Benefits transfer (e.g., how does one transfer the lessons and results from one setting to another);

- Pricing and access (e.g., revenue generation, fee structure, price discrimination);

- Design issues (e.g., sizing effects and carrying capacity) and distributional considerations.

These topics are discussed in the following sections of this report. For each topic, we characterize how it has been treated in existing work to date on marine reserves. Further, we propose the preferred methodological treatment or state-of-the-art.

Our purpose is neither to provide a handbook on how to conduct net benefit evaluation nor a presentation of case studies. Rather we seek to provide a window to the relevant literature on marine reserve valuation and to summarize some general, but hopefully useful, conclusions from this and related literature to help policymakers think critically about marine reserve valuation issues and about specific cases.

Our method has involved a survey and review of the relevant literature on marine reserves. In Table 1, we relate each publication to its coverage of each of the topics identified above. We use the following key:

- D=topic is discussed

- T=theory on the topic is developed or reviewed

- A=empirical analysis of the topic is conducted.

When one of these letters is followed by a dollar sign in parentheses ($), the relevant publication reports on or develops specific dollar estimates of benefits or costs. The literature represented in the table is discussed in greater depth in the following sections.

Table 1
Comparison of Published Studies Related to the Evaluation of Net Benefits of Marine Reserves

	B/C Sources	Market Values	Nonmarket Values	Biological Diversity	Benefits Transfer	Pricing/ Access	Design Issues	Equity Issues
Barton 1994	D($)	D($)	D($)	D	D			
Bennett 1984	A		A($)		D			
Broadus 1988	T	D	D			T		
Broadus et al. 1984	D	D	D	D		D	D	
Carpenter and Maragos 1989	D	T					D	
Chaloupka 1987	D							A
CNPPA 1994	D	D	D	D			A	
Cocks 1984	D			D			T,A	D
Dixon 1993a	D	D($)	D($)	D		D		
Dixon 1993b	D	D	D	D				
Dixon 1993c	D	D($)	D($)					
Dixon and Hodgson 1988	D	A($)		D				D
Dixon, Scura and van't Hof 1993	D	D($)				D($)	D	D($)
Dixon and Sherman 1991	D	D	D	D		D	D	D
Dixon and Sherman 1990	D	D($)	D($)				D	
Dixon and van't Hof 1995	D($)	D	D	D				D

	B/C Sources	Market Values	Nonmarket Values	Biological Diversity	Benefits Transfer	Pricing/ Access	Design Issues	Equity Issues
Doeleman 1991	T	T	T				D	D
Echeverría et al. 1995*	A($)		A($)	D				
Edwards 1991	A($)	A($)	A($)		D	A($)		D
Edwards 1987								
Ehler 1994	D						D	
Farrow 1994	D	D	D	D			D	
Foster and Lemay 1986	D	D	D			D	D	
Freeman 1993b	D($)	D($)	D($)		D			
Gubbay 1993	D						D	D
Heyman 1988	D($)	D($)	D($)	D				
Hoagland 1983	D						D	D
Hodgson and Dixon 1992	A($)	A($)		A	D			
Hundloe 1989	D($)	D	D($)					
Kaoru and Broadus 1994	D	A($)	A($)					
Kaoru and Hoagland 1994	D($)	D($)	D($)			D	D	
Kenchington 1989	D						D	
Kriwoken 1991	D						D	D
Kriwoken and Haward 1991	D						D	D
Leeworthy 1993	D	D	D			A		
Leeworthy 1991	A($)		A($)					

	B/C Sources	Market Values	Nonmarket Values	Biological Diversity	Benefits Transfer	Pricing/ Access	Design Issues	Equity Issues
Leeworthy and Wiley 1994	A($)		A($)					
Leeworthy and Wiley 1993	A($)		A($)					
Leeworthy and Wiley 1991	A($)		A($)					
Lindberg 1990	D($)	D($)	D($)			T($)	D	D
Lindsay and Tupper 1989	A($)		A($)					
Mattson and DeFoor 1985	A($)	A($)						
McAllister 1988	D($)	D($)	D	D($)				
McNeely and Dobias 1991	D	D				D		D
Meganck 1991	D($)	D($)				D($)	D	
Miller 1981	T	T	T	D				
Miller and Ditton 1986	D	D	D					
Munasinghe 1993	D($)	D($)	D($)					
Pendleton 1994	A		A($)					
Polunin 1990	D	D	D	D			D	D
Repetto and Solow 1991	T	T	T	D			T($)	
Reynolds 1991	A($)	A($)	D					
Salm and Clark 1984	D	D	D	D		D	T	D
Spurgeon 1992	D	D	D					
Sterling Hobe Corp. 1980	A($)							A($)

	B/C Sources	Market Values	Nonmarket Values	Biological Diversity	Benefits Transfer	Pricing/ Access	Design Issues	Equity Issues
Tisdell 1991	T	T	T			D	D	T
Tisdell 1988	T	T	D			T		
Tisdell and Broadus 1989	T	T	T	D			T	D
Tisdell et al. 1992	T	T		D				
van't Hof 1989	D($)	D($)				D($)		
van't Hof 1986								
Westing 1994	D	D	D					D

Key: T=theory on the topic is developed or reviewed; D=topic is discussed; A=empirical analysis of the topic is conducted. When one of these letters is followed by a dollar sign in parentheses ($), the relevant publication reports on or develops specific dollar estimates of benefits or costs. An asterisk (*) indicates that the study does not focus explicitly marine or coastal reserves.

2 Sources of Benefits and Costs

Introduction

General categories of benefits and costs arising from the creation and operation of a marine reserve are summarized in Table 2. In examining these categories, it is perhaps simplest to think about a once-and-for-all decision to create a marine reserve of a certain size and with a specific set of rules in place that permit a specific set of uses of the reserve's resources. Given these parameters of size and regulatory scope, gross benefits and opportunity costs can be calculated for the present and forecasted for the future.[1] Net benefits can be discounted over time to determine whether or not a reserve should be established.

Ideally, this kind of analysis should be performed for the reserve whenever socioeconomic or environmental characteristics change significantly to ensure that the reserve's size and regulatory scope are always "optimal" in an economic sense. As an example, Figure 2, from Butler (1980), shows the potential for the decline in tourist benefits over time as a tourist site matures.

An important class of benefits associated with the creation of a marine reserve is the prevention of irreversible environmental effects. Some types of industrial developments, resource uses, or waste disposal may result in changes to environmental conditions in a marine area such that it cannot be restored to its original condition. As a result, certain uses may be foreclosed permanently. The postponement or prevention of irreversible developments, thereby allowing uncertainties about benefits and costs to be resolved, can be an important benefit of a marine reserve designation.

In reality, there may be costs associated with observing changes in socioeconomic or environmental characteristics. These costs may be large enough to preclude the continual reevaluation of the net benefits of a marine reserve.[2] There may be costs involved as well in modifying a reserve's size or regulatory scope, which we might describe as political process costs.[3] Costs of observing changes and modifying a reserve designation imply that policy decisions to create a reserve are, to some degree, inflexible.

To many observers and interests, the concept of policy inflexibility may be the whole point to designation of a reserve.[4] To these individuals, some resources or uses are so valuable that they should be protected, or given priority within a reserve, with rules that are costly to modify. Indeed, the concept of policy inflexibility is sometimes carried to an extreme through the promulgation of rules that *increase* the costs of gathering information on environmental characteristics, such as through prohibitions on energy exploration, for example.

Our purpose here is not to assail purposeful policy inflexibility but to draw the reader's attention to its potential costs. In a real sense, this point is the converse of that made in the literature on "irreversible development" (e.g., Usategui 1990; Miller and Lad 1984; Arrow and Fisher 1974). In examining Table 2, the reader should be aware of the potential restrictive effects of policy inflexibility on

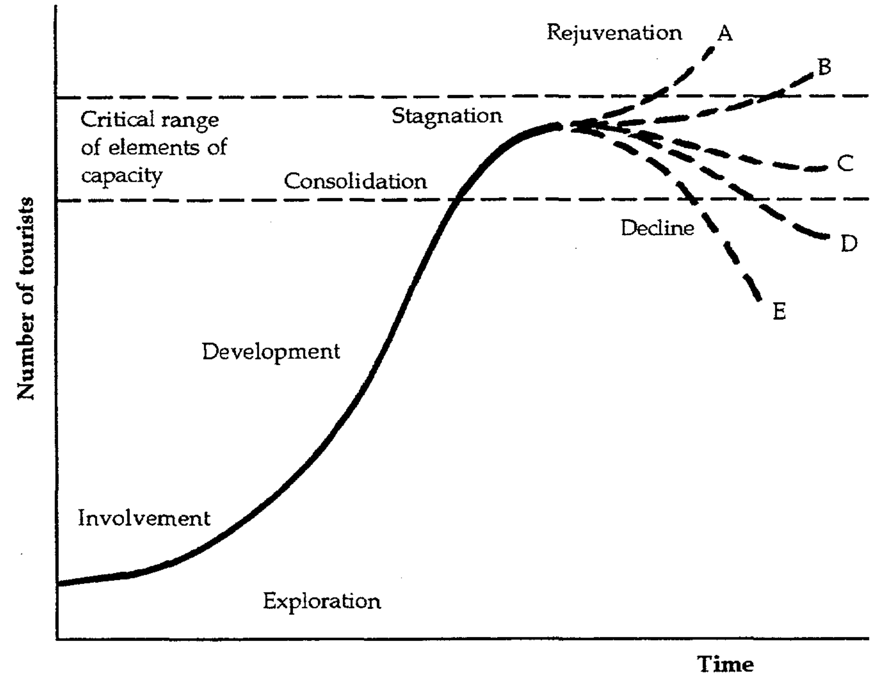
Table 2
Marine Protected Areas: Sources of Benefits and Costs

BENEFITS:	COSTS:
	Purchase of land and facilities
Strengthens Property or Liability Rights to a Clean Marine Environment	
New or Improved Opportunities; Tourism; Diving; Boating; Recreational Fishing	Foregone Opportunities: Mineral ED&P; Waste Disposal; Commercial Fisheries; Treasure Salvage; Shipping; Tourism
Facilitates Natural Resource Management: Rare Ecosystems/Species/ Stocks/Cohorts; Habitat/Refugium	Administration Monitoring/Enforcement
Facilitates Cultural Resource Management: Archaeological Study; Resource Protection; Recreation "Targets"	Administration Monitoring/Enforcement
Oceanographic Research: Control Area; Ecosystem Studies; Public Education	Research and Education Costs
Positive External Effects: Buffer Zone; Increased Assimilative Capacity; Onshore Development Opportunities	"Paper Park:" Benefits Small or Nonexistent and Industrial Development Opportunities Foregone
Prevents Development that is Costly to Reverse	Results in Zoning Decision that is Costly to Reverse
Nonmarket Benefits: Option; Vicarious/Bequest; Existence	Nonmarket Costs: Option
Conceptual Simplicity of Boundary	Economic Aspects of Size Rarely Considered

updating and reevaluating the net benefits of a reserve.

All of the literature we have surveyed refers to, but does not necessarily quantify or estimate, sources of benefits from the creation of a marine reserve. In general, a zoning decision to establish a marine reserve will require some justification, such as the identification of priority uses, accompanied by reasons for specific use rankings. Salm and Clark (1984) suggest one way to rank conservation objectives by type of conservation area (Table A.1, Annex A). In most cases of the creation and operation of marine reserves, economic quantifications of these kinds of

Figure 2
The "tourism cycle"



Source: Lindberg, 1990. Reprinted with permission of Canadian Association of Geographers, Montreal.

benefits have not been attempted explicitly.[5] We review specific cases of benefit estimation, including market and nonmarket benefits, in the next two sections.

Reserves located onshore and in the coastal zone may require the purchase of land and capital infrastructure. Although these purchases may be required for marine reserves too, they are unlikely to represent a major component of costs for marine reserves. In the majority of cases, published estimates of these costs, which appear to be straightforward to calculate, have not been attempted explicitly. We believe that access to unpublished or limited-distribution government documents surely would reveal some attempts at estimating the costs of land and infrastructure purchases as well as the costs of administration and monitoring or enforcement.

Administrative costs are likely to be important, but the extent to which they are incurred may depend upon the relevant circumstances, i.e., whether or not the designation is a "paper park," which is created but not managed, monitored, or enforced in any way and therefore involves no administrative costs.

In many cases, the largest sources of costs are likely to be those associated with foregone commercial development opportunities. Restricted or excluded uses generating opportunity costs often are recognized and described as "noncompatible" uses, and sometimes arrayed as in Table A.2 (Annex A) from Polunin (1990) in a "use-compatibility matrix." In the United States, the designation of a marine sanctuary has often been considered to be a regulatory action having a "significant impact" on the U.S. economy. If so, regulatory impact analyses, as required by executive order, are performed.[6] The designation of the U.S. Channel Islands National Marine Sanctuary is an example. A regulatory impact analysis conducted for that sanctuary (SHC 1980) examined the opportunity cost of, among other things, foregone hydrocarbon development opportunities in the area (see Hoagland 1983 for a case study).

Once priorities have been set, legislation is enacted or rules are promulgated to reflect these priorities. These rules are almost always site-specific, but Table A.3 (Annex A), from Polunin (1990), and Table A.4 (Annex A), from Foster and LeMay (1989), provide general examples of the kinds of rules promulgated to govern the uses of a marine reserve.

Proposals to create and manage a marine reserve can involve contentious issues of preservation versus development. These issues are usually resolved in relevant political fora. Analyses of the tradeoffs between benefits and costs never are, and should never be, the *only* basis for marine reserve decisionmaking, but they can be an extremely important source of information on the relevant tradeoffs. As a methodological treatment, analyses that fall short of quantifying sources of benefits and costs should be considered less than adequate because those involved in decisionmaking have access to an incomplete or biased information base.

Some authors have criticized the estimation of benefits and costs as an input into decisionmaking on the basis that such estimation will never be capable of quantifying all benefits, thereby creating a bias in favor of commercial development of marine areas (Salm and Clark 1984). Dixon and Sherman (1990) demonstrate, however, that in many cases "market" benefits alone can justify, on an economic basis, the creation of a marine reserve.

Barton (1994) summarizes the components of "total economic value," including use and nonuse values (Figure 3). Generally, values identified in the figure as "direct uses" are those most likely to be observable in markets. Values identified as "indirect" and "nonuse" are less likely to be observed in markets. However, not all direct uses are market-observable. For example, benefits resulting from research uses are not always traded through markets. Further, some nonuse values are incorporated into marketable commodities, such as aesthetic views from coastal properties.

Table A-5 (Annex A), from Spurgeon (1992), displays subjectively determined "multipliers" or weights for the values of different uses as components of "total economic value." In practice, such weights have little empirical justification and are not much more than a qualitative elaboration of the priority ranking methods described above. A state-of-the-art evaluation would estimate the components of total economic value in Barton's figure as inputs into a decision of whether or not to create a marine reserve.[7]

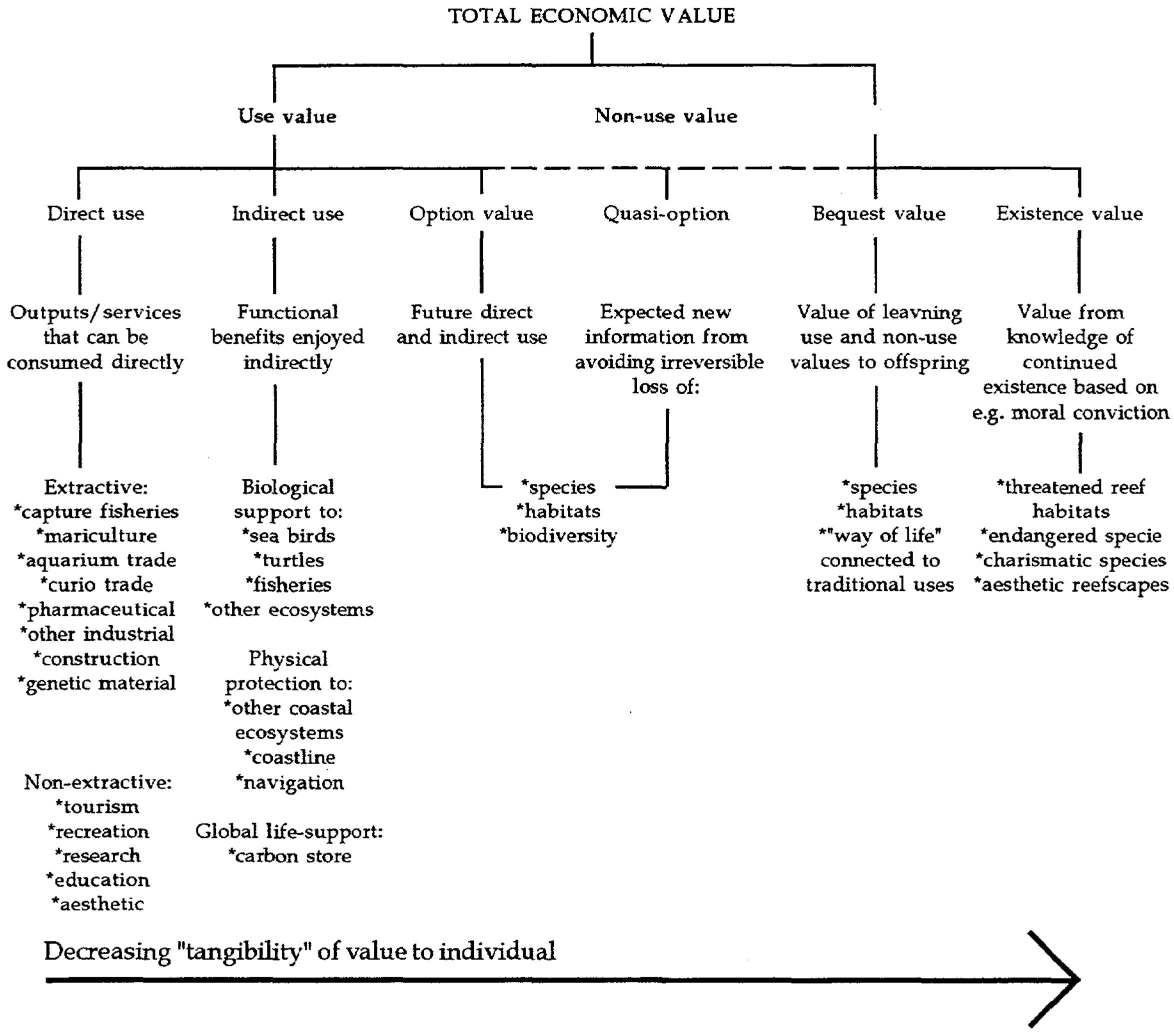
Estimates of costs are extremely important to a net benefit analysis, although they are often neglected in the valuation literature. Freeman (1993a:488) notes that "proper measurement of costs involves the *same kinds* of problems as, and is likely to be as difficult as, the measurement of benefits of environmental improvement" (emphasis added). Swallow (1994) provides a good example of the kind of analysis needed to analyze the tradeoffs between coastal development and preservation, integrating renewable and nonrenewable resource management theories.[8]

Financial Accounting and Market-Observable Measures of Benefits and Costs

In many cases, market-observable measures of benefits and costs can be relatively straightforward to calculate. Basic theory is explained in the work of Tisdell (1991, 1988) and Dixon and Sherman (1990). Methods are described in the work by Carpenter and Maragos (1989) on environmental assessment techniques for tropical islands and coastal areas. (All estimates reported here and in Tables 3a and 3b are expressed in 1995 dollars using the U.S. consumer price index to adjust for inflation.)

Market-observable benefits may include tourism revenues and commercial fishery harvests. Market-observable costs may include

Figure 3
Economic values attributed to a coral reef environment



Source: Barton, 1994. Reprinted with permission of Canadian Association of Geographers, Montreal.

foregone development opportunities, administration, monitoring and enforcement, employee wages, and infrastructure construction and maintenance, for facilities such as visitors centers, marine scientific research laboratories, airports, or wharves.

Market-observable benefits and costs can be compared to assess whether or not a marine reserve should be established or continue to operate. An excellent example of this kind of analysis is the study by Hodgson and Dixon (1992) (see also Dixon and Hodgson 1988) of the effects of sedimentation on coral reefs from coastal forestry practices at Bacuit Bay, Palawan Island, in the Philippines. The authors employ an analytical approach which they call "change in productivity" to compare discounted gross revenues from two alternatives involving either the prohibition or the permission of coastal logging operations. Logging operations are costly in the sense of reducing the productivity of both fishing and tourism. The authors find that a prohibition on logging is $25 million more productive than continued logging. Although their study does not pertain specifically to a decision about the establishment of a marine reserve, its method of analysis can be adapted to marine reserve cases in a straightforward manner.[9]

Most of the literature describes unquantified market-observable benefits and costs, but a significant proportion reports on specific case studies that have estimated these benefits and costs. Tables B-1 and B-2 (Annex B), from Barton (1994), are examples of these kinds of descriptive surveys of market-observable *benefits*. Placing estimates such as these together in one table begs the question of whether or not the estimates are really comparable. We discuss this question in Chapter Three under the topic of benefits transfer.

Studies of economic "impacts" employ multiplier techniques to measure the full impacts of market transactions. The rationale for economic impact analyses is that, because any market purchase of goods and services also involves market purchases of inputs to produce those goods and services, the full economic impact of, say, a tourist visit ripples through the economy. Multipliers help to measure these impacts. For example, Reynolds (1991) employs a survey of local businesses to estimate gross annual income earned from the use of the U.S. Channel Islands National Marine Sanctuary of between $3 to 7 million. Recreational expenditures are believed to add another 1.5 to 3 times the gross annual income, suggesting that annual economic impacts are on the order of $4 to 20 million at that reserve. Dixon, Scura and van't Hof (1993) report revenues of approximately $26 million associated with the Bonaire Marine Park in the Netherlands Antilles. Table B-3 (Annex B) from Heyman (1988) presents a comparison of income generated by other marine parks in the Caribbean.

Although governments might be interested in measuring economic impacts for political reasons, economic impact analyses are not very useful in estimating the net benefits of marine reserves.[10] A good critique of an economic impact analysis in the case of the U.S. Virgin Islands National Park, a coastal and marine reserve, can be found in Dixon and Sherman (1990).

If costs are market-observable and can be fully accounted for, and the market-observable benefits of creating a marine reserve exceed these costs, then a net benefit evaluation can be used to support a decision to establish a marine reserve (Dixon 1993a, 1993b, 1993c).

A more efficient approach would entail an examination of the relationship between marginal benefits and marginal costs as a function of the size or regulatory scope of the reserve (see Chapter Five, *Reserve Area Design Issues)*. Absent a measure of *both* market and nonmarket benefits, the approach suggested here cannot be used to estimate the economically efficient size or regulatory scope.

Nonmarket Measures of Benefits and Costs

Expenditures for recreational activities are only one component of broader classes of benefits provided by marine reserves (Figure 3). Two classes of nonmarket benefits exist: "use" and "nonuse" (Freeman 1993a).[11] Use benefits are derived from the actual contact that tourists or residents have with marine resources from visits or residence adjacent to a reserve. Nonuse benefits are intangible; they arise from the satisfaction that individuals may experience from the preservation of a marine reserve in the absence of any actual physical use.

Nonuse values can be further divided into option, bequest, and existence values. *Option* value (Weisbrod 1964) is defined as the premium over expected future benefits from a marine reserve that individuals may be willing to pay to preserve access to and use of the resources of the reserve in the future. Option value is influenced by an individual's risk attitudes over uncertain future benefits.[12] *Bequest* value (Sutherland and Walsh 1985; Walsh, Loomis and Gillman 1984) is defined as an individual's willingness-to-pay (WTP) for the satisfaction of preserving a particular marine reserve for future generations.[13] *Existence* value (Krutilla 1967) is defined as an individual's WTP for the establishment of a marine reserve when the individual is certain that she will never visit the reserve or use its resources.[14]

Another component to program evaluation is sometimes known as "quasi-option value." *Quasi-option* value is defined as the value of information gained by delaying a decision to proceed with uses of marine resources that result in irreversible effects. Quasi-option value is not an element of individual WTP. Rather it is the value to the decisionmaker (government or marine reserve manager)[15] of taking a rational approach to investments in the presence of uncertainty, where the development of new information about socio-economic or environmental characteristics may reduce the uncertainty (Freeman 1993a).

Theoretical approaches are exemplified by several studies. Doeleman (1991), Tisdell (1991), and Tisdell and Broadus (1989) develop general theoretical approaches to net benefit evaluation, including nonmarket values, in the case of marine reserves. Using an onshore example, Miller (1981) examines the tradeoff between irreversible development and the preservation of habitat for endangered species.[16] Miller finds that, if the preservation of species is valued by society, and if development is costly to reverse, then the rate of conversion of habitat to development purposes will be too rapid. The socially optimal rate depends upon the value of a marine area in its different uses and the cost of reversing developed areas to species habitat. Miller (1981:25) states that:

> The service flow of [a marine reserve] as species habitat is certain to be neglected in decentralized market decisions concerned with the production of usual economic goods and services. Should actual empirical analysis or informal guesswork demonstrate the existence of utility value for species stocks (a value *assumed* in this paper), collective action will be necessary. However, the design of efficient mechanisms to internalize the consideration of habitat values in [marine resource] use decisions will be difficult, at best.

Doeleman (1991:420) reaches a conclusion similar to Miller's, but goes one step further in stating that "[it] may be preferable to approach the allocation of [marine] wilderness by a prior zoning decision." Optimal marine zoning decisions require evaluation of total net benefits, including nonmarket benefits and costs.

In estimating nonmarket values, analysts employ either "indirect" or "direct" valuation methods (Braden and Kolstad 1991). The best recent survey of theory in this area is by Freeman (1993a). Specific applications of nonmarket valuation techniques are explained in many sources (for recent surveys see Munasinghe 1993, Freeman 1993b, or Mitchell and Carson 1989). In Table 3a, we present some published estimates of nonmarket economic benefits of preserving marine and other natural areas.

The "travel cost model" (TCM) is the most widely applied indirect method for measuring recreation benefits (Bockstael, McConnell, and Strand 1991). The TCM uses observed behavioral choices of whether or not to visit one or more marine reserves or other sites to evaluate individual recreational benefits. These benefits can be aggregated to estimate demand for the "environmental services" of a marine reserve.

Several recent marine or coastal applications of TCM are not focused specifically on evaluating the benefits of marine reserves, but instead focus on benefit estimation of coastal or marine areas or features. In the United States, the National Oceanic and Atmospheric Administration (NOAA) has collected information useful for estimating travel cost models for over 50 coastal sites.[17] The results of these studies have been compiled into a "meta-database" available on CDROM disk (Leeworthy, p.c., 1995).

At NOAA's Strategic Environmental Assessment Division, Leeworthy and Wiley (1994, 1993, 1991) and Leeworthy (1991) have estimated consumer surplus using the TCM for eight coastal beaches in the United States, including the combined John Pennekamp Coral Reef State Park and the Key Largo National Marine Sanctuary, a coastal and a marine reserve. In making these estimates, the authors investigated a number of model specifications and functional forms. In general, only travel costs, and not socioeconomic attributes, are significant determinants of the number of trips to a site, although the reader should refer to each study for specific details. These estimates are compared with some CVM estimates from New England beaches (Lindsay and Tupper 1989) in Table 3b.

The TCM estimates for consumer surplus for the one marine and coastal reserve on the list stand out by an order of magnitude. Although Leeworthy (1991) does not hypothesize a reason for this, it may be due to the national importance of this site, drawing visitors from all over the country. NOAA is now planning a larger effort to estimate TCM models for the newly designated Florida Keys National Marine Sanctuary.

Hedonic demand analysis (HDA) is another indirect nonmarket valuation technique. HDA takes advantage of the fact that, under some circumstances, environmental quality can be thought of as an attribute of a differentiated private market good (Rosen 1974). A good example is the premium commanded by homes with waterfront views. Brown and Mendelsohn (1984) developed an hedonic TCM to value recreational fishing visits. Edwards (1991) used HDA to estimate the demand for Galapagos Islands vacations by ecotourists, finding average WTP for per tourist-day of $439 (the Galapagos are an Ecuadorian National Park and an International Biosphere Reserve).

The contingent valuation method (CVM) is the only method available for estimating nonuse values. CVM is a direct survey valuation method. CVM surveys establish a hypothetical market where respondents can "purchase" the environmental attributes of a marine reserve by stating their total WTP.[18] Sometimes it is possible with a CVM survey to break-down total WTP into existence, option, or bequest values (Kaoru 1993; Walsh, Loomis and Gillman 1984).

Bennett (1984) conducted an early CVM survey of the Nadgee Nature Reserve, a coastal reserve in Canberra, Australia. He estimated existence values only, and respondents were willing-to-pay an average *one-time* lump sum for preservation of the reserve of approximately $65. More recently, Kaoru and Broadus (1994) estimated the WTP of residents and tourists for the establishment of a "harbor preservation fund" in Wellfleet, Massachusetts using CVM techniques. Wellfleet residents were willing-to-pay on average $66 *annually* for preservation of the harbor. Using CVM techniques, Kaoru (1993) estimated annual average household use ($42), option ($24), and existence ($97) values for improvements in water quality at three coastal ponds in Martha's Vineyard, Massachusetts.

A significant body of literature focusing on evaluating the benefits of marine recreation is related to marine reserve valuation. Freeman (1993b) has conducted a recent survey, finding an extensive literature documenting significant economic values associated with access to marine recreational fishing sites, but a limited literature documenting the value of access to beaches for sunbathing and swimming, and almost no literature documenting the value of access to the ocean for boating activities other than fishing. Freeman also found little evidence that water quality variables play an independent role affecting marine recreational fishing values. Water quality is a more important determinant of beach visits however, and, in a related study, Pendleton (1994) has estimated dive site visitation based upon indicators of coral reef quality in Roatan, Honduras.

Some early efforts at valuation exercises were clearly inadequate. A good example is presented in Table A.6 (Annex A), from Salm and Clark (1984). According to this method, criteria affecting tourism and conservation "values" are subjectively scored to determine priorities (cf., Spurgeon 1992). While some would argue that such methods may be better than doing noth-

Table 3.A
Comparison of economic valuation estimates for marine reserves

Marine Area	Location	Year	Mean Value ($)	Model Type	Mean Income ($000)	Mean Age (yrs)	Multiple Destinations	Source
John Pennekamp/Key Largo	Florida	1988-89	356-533	TCM	59	47	yes	Leeworthy 1991
Galápagos National Park	Galápagos	1986	439	HDA	45	53	no	Edwards 1991
Great Barrier Reef[1]	North Queensland	1985-86	228[d] 138[i]	TCM	-- --	-- --	no	Hundloe 1989
Martha's Vineyard[2]	Massachusetts	1989	164	CVM	109	52	no	Kaoru 1993
Bonaire Marine Park[4]	Netherlands Antilles	1991	132	--	--	--	no	Dixon, Scura and van't Hof 1993
Wellfleet Harbor[3]	Massachusetts	1994	66[d] 87-111[i]	CVM	46[d] 70[i]	56[d] 45[i]	no[d] yes[i]	Kaoru and Broadus 1994
*Monteverde Cloud Forest[3]	Costa Rica	1991-92	7[d] 6[i]	CVM	21[d] 62[i]	-- --	no	Echeverría, Hanrahan and Solórzano 1995
*Nadgee Nature Reserve[3,5]	New South Wales	1979	3	CVM	50	36	no	Bennett 1984

Including estimates from land-based and coastal reserves. This table illustrates some of the difficulties involved in making comparisons across sites. All values are per person per day, unless otherwiseindicated, and they have been expressed in 1995 U.S. dollars using appropriate exchange rates and price indexes. Where values were estimated as one-time payments (see *), an annual payment has been calculated by multiplying the one-time payment (capitalized asset) by a discount rate of five percent. In some cases, annual estimates may be similar to daily estimates if areas are visited only once each year. Care should be taken in making comparisons of these types because of differences in modelling approaches, socioeconomic characteristics, and choices faced by individuals surveyed for each area. The reader is urged to examine each of the relevant studies for greater detail.

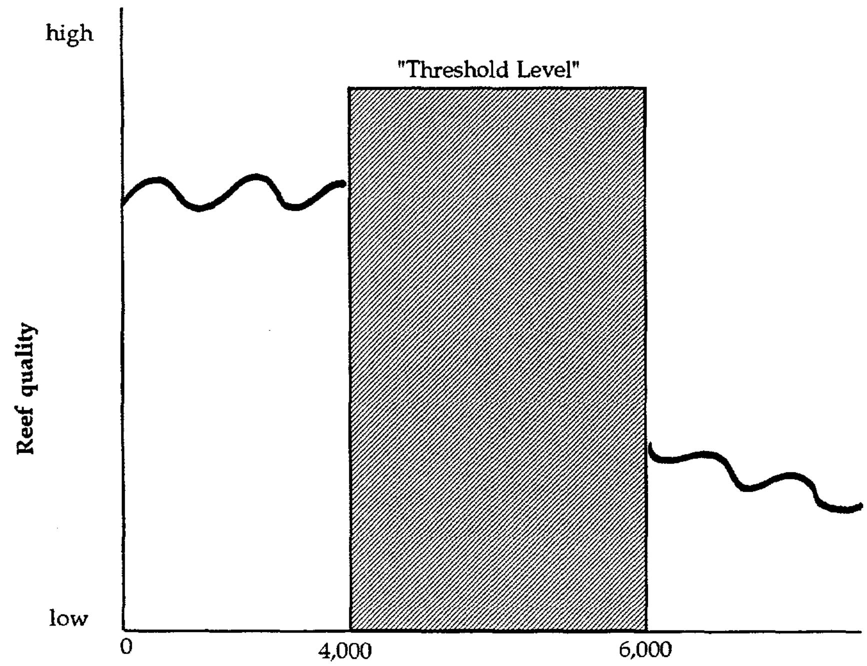
Key: (1) values are per person per year; (2) annual willingness to pay for water quality improvements at three coastal ponds; (3) annual payment for preservation in perpetuity; (4) values are average economic impacts (gross revenues) per dive for 1991; (5) estimated existence value only. Some analysts have estimated different values for domestic or residential (d) and international or tourist (i) valuations.

Table 3.B
Published estimated consumer surplus values per person per day for beaches in the United States

Beach	Location	Year(s) Surveyed	Estimated Consumer Surplus ($)
John Pennekamp Coral Reef State Park and Key Largo National Marine Sanctuary	Florida	1988-89	356-533
Island Beach State Park	New Jersey	1988	20-30
Santa Monica County Beaches	California	1989	23
Leo Carillo State Beach and San Pedro Bay Beaches	California	1989	65
Cabrillo Pier and City of Long Beach	California	1989	10
Clearwater Beaches	Florida	1989-90	67-75
Honeymoon Island State Park	Florida	1989-90	18-20
Old Orchard Beach	Maine	1988	67
Pine Point Beach	Maine	1988	61
Ocean Park Beach	Maine	1988	68
Seabrook Beach	New Hampshire	1988	54

The shaded box is a combined coastal and marine reserve. The top estimates are obtained from TCM models run by NOAA's Strategic Environmental Assessments Division. The bottom four estimates are obtained from CVM models (Lindsay and Tupper 1989). Estimates are rounded to the nearest dollar and expressed in 1995 dollars.

Figure 4
Diving intensity and threshold stress level on a coral reef



Source: Dixon, 1993a.

ing, they are clearly subject to the biases of the scorer. Where feasible, such methods should be complemented or replaced by the valuation techniques described above. Where feasible, multiple nonmarket valuation techniques might be employed, such as both TCM and CVM, to help correct for any potential biases a specific technique may have and to obtain robust measures of net benefits. Such an approach is being planned to evaluate recreational use benefits in the Florida Keys National Marine Sanctuary (Leeworthy, p.c., 1995).

In addition to the direct monetary costs of investment in and operation of a marine reserve, nonmarket environmental costs may be involved. For example, Dixon 1993b demonstrates the qualitative effect of "stress" resulting from scuba diving on the biological diversity and cover on a coral reef (Figure 4). Open-access fishing may result in excessive effort applied to a recreational fishery in a marine reserve or may involve "bycatch" of nontarget species. Local residents may feel deprived of their "way of life" due to tourist congestion or coastal development.

The valuation methods described above can be applied to measure these kinds of nonmarket costs. The negative impacts on the marine environment are valued as negative benefits to visitors, residents, and nonusers with existence value.

Valuation of Biological Diversity

In most cases, the literature on evaluation of marine reserves describes the presence of rare biological resources, abundance of species, or unique ecosystems as one of the primary reasons for establishing and managing a reserve. Several studies account for fisheries production,[19] but only a few studies have attempted to estimate the value of fisheries production, either as a benefit of the marine reserve or as an opportunity cost (Hodgson and Dixon 1992; Dixon and Hodgson 1988; McAllister 1988). Polunin and Roberts (1993) estimate the value of commercial fish stocks in the Netherlands Antilles' Saba Marine Park and in Belize's Hol Chan Marine Reserve. These authors find that the commercial value of stocks in these reserves are 2.2 to 3.5 times higher than in heavily fished areas. However, the stocks located in the marine reserves are not harvested commercially, thereby limiting the usefulness of this approach as a measure of benefits.[20] None of the studies we examined attempt to estimate the nonmarket value of biological resources, ecosystems, or biological diversity, except possibly indirectly as a component of the total economic value of a marine reserve.[21] None of these studies attempt to factor out of the total value an estimate of the nonmarket benefits of biological resources, ecosystems, or biological diversity.

Marine recreational fishing evaluation studies, surveyed by Freeman (1993b), are relevant here. Freeman finds that there are "significant economic values" associated with access to *marine recreational fishing* sites. He makes several ceteris paribus hypotheses from his survey of the literature. First, for a site of a given size, the average value per person or per trip is likely to fall as the geographic size of the *market* is expanded, including more people and more substitute sites. Second, the value of access to all species is likely to be greater than the value of access to a single species. Third, for a market of a given size, the value per person or per trip is likely to increase with the size of the *site* being valued, as substitute sites become incorporated into the site being valued. These hypotheses raise important issues for marine reserve evaluation and design, but Freeman finds that they cannot be tested with the data collected from the studies that he surveyed. They remain important factors to be considered in future net benefit evaluations for marine reserves.

For the most part, the literature on marine reserves has ignored evaluation of biological diversity, per se. In some of the literature, the conservation of biological diversity is cited as as an appropriate objective, where diversity is usually taken to mean the abundance of different species, also known as "species richness" (Polunin 1990; McAllister 1988). The preservation of species and genetic diversity in this sense has been taken to be one of the main purposes of management in a marine reserve by Fourth World Congress on National Parks and Protected Areas (CNPPA 1994).

Three general questions arise from the notion that there is value to conserving biological diversity: (1) What is biological diversity? (2) How can we measure it? (3) How do we conserve it? Recent work has shed light on all of these issues, but to our knowledge it has not been applied specifically in the evaluation of marine reserves and their biological resources.

Solow and Polasky (1994) have described diversity as the *joint dissimilarity* of a set of species. Dissimilarities are based upon differences between species, known as *distances*, in genetic, behavioral, morphological, or other characteristics relevant to management or valued by society.[22] This description is in contrast to *species richness*, which regards distances between any two species, no matter how closely related, as identical. Solow, Polasky, and Broadus (1993) define distance to be the minimum distance between an individual species and a specified set of species. The authors then define and investigate measures of diversity as functions of this definition of distance.[23]

Given a set of species to protect from extinction[24] when limits on financial resources available for conservation constrain the number of species that can be protected, a relevant policy question is: Which species should be protected? Solow, Polasky, and Broadus (1993) examine choices of subsets of species that minimize *expected* losses of diversity through extinction events. In their model, the probability that a species will become extinct may depend upon its own population size and any ecological interactions with other species. Assessment of these extinction probabilities is an important input into their analysis. This approach does not consider explicitly the value of biological diversity, except that a reduction in biodiversity through extinctions is assumed to be something that society wants to avoid.

In a separate paper, Polasky, Solow, and Broadus (1993) consider the relative option values of conserving different sets of species.[25] Option values arise because of the uncertain value of species as a source of future benefits, such as for medicines. The total option value of any set of species is assumed to depend upon the diversity of the set. Closely related species are modeled as potential substitutes, making biologically diverse sets more valuable in the sense of option value. Their model maximizes option value subject to constraints on resources for management.

These studies do not explicitly consider other sources of value for one species or a set of species, including market, existence, or bequest values. Some species, such as marine mammals or sea turtles, can be very valuable for these reasons, commanding the lion's share of conservation resources. An interesting result of the work referred to here is that the preferential protection of highly valued species can affect the option value of other species.[26] Moreover, the preferential protection of a highly valued species can affect the pattern of extinctions of other species with which it interacts, thereby influencing biological diversity over the long term. These results reinforce the long-understood bioeconomic need for understanding species interactions (see generally Clark 1990).

Once sets of marine species have been identified for protection through these methods, an issue remains of how best to protect them. Solow (1993) concludes that habitat preservation may be the best way in which to conserve sets of species. An important feature of these methods for marine reserve management is that they help to identify priority habitats for protection as reserves. We note again that the net benefits of a marine reserve may change over time. In particular, these benefits may change with changes in stock levels or biological diversity.

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1 Alternative reserve sizes and regulatory scopes can be compared to determine the "optimal" size and regulatory scope.

2 As a result, there is theoretically an optimal level of information collection to observe changes in socioeconomic and environmental characteristics (see Crocker 1975).

3 An important issue exists concerning the effects of policies that *are perceived to be* reversible, including the possibility of costly rent-seeking. We know of no studies that have examined this issue directly.

4 Indeed, many people may believe that reserves should be established for certain purposes in perpetuity.

5 It is possible to interpret a priority ranking such as that displayed in Table A.1 (Annex A) as a type of preference ranking by experts in the field. We discuss this in more detail below in Chapter Four (see also Cocks 1984). This interpretation raises questions of whether expert preferences are reflective of societal preferences or whether social welfare is increased through the reliance solely upon expert "valuations." In this report, we will assume that the answers to both of these questions are in the negative.

6 Legislation currently pending in the U.S. Congress would make such analyses more common.

7 So long as all of the components of total economic value are being considered, it is not necessary to estimate the components of total economic value separately, although some recent studies have begun to do so. See Kaoru (1993) for a study differentiating use and nonuse values for coastal pond water quality improvements on Martha's Vineyard, Massachusetts. Cicchetti and Wilde (1992) explain that in some cases it may not be possible to decompose total value into its individual components.

8 Swallow's analysis was not conducted in the specific context of a marine reserve.

[9] As discussed in the next section, other benefit and cost items may not be observable, implying that analyses only of market-observable benefits and costs are a crude first approximation to a serious economic analysis.

[10] Economic impact analyses may result in double-counting of benefits or costs, and, as such, cannot be relied upon to make accurate evaluations of net benefits.

[11] Nonuse benefits are sometimes referred to as "passive" use benefits.

[12] The premium is not just a simple function of either the existence or the degree of risk aversion. Freeman (1993a:263-264) explains that option value represents the difference between two unique measures of welfare: expected net benefits and the sum of the option value and expected net benefits, which is termed *option price*. Neither welfare measure is better than the other, and Freeman feels that it is "time to expunge option value from the list of possible benefits." Other analysts disagree. Option value is sometimes just measured as a component of total value reflecting the value of possible use of a natural resource in the future (cf., Kaoru 1993).

[13] A related concept is *vicarious* value, which is roughly identical to bequest value except that it refers to the current generation.

[14] Some controversy still surrounds the concept of existence value. Cicchetti and Wilde (1992) have argued that existence value is not an operational concept in economics, but other economists disagree.

[15] In most countries, the government, as agent, manages the marine reserve for the public, as principal.

[16] This hypothetical example is easily applied to a marine setting.

[17] These studies are part of an intergovernmental effort in the United States known as the Public Area Recreational Visitors Survey (PARVS), involving seven federal and twelve state agencies.

[18] The CVM has not been accepted unconditionally by the economics profession. Haneman (1994) and Diamond and Hausman (1994) provide two different perspectives on the debate. In general, a thorough, credible CVM study may require extensive efforts and may be quite costly.

[19] The U.N. Food and Agriculture Organization publishes statistics on international fisheries output. It does not report on prices or value of production.

[20] The authors hypothesize that recruitment of stocks located outside the marine reserves may take place from stocks within the reserves.

[21] But see Pendleton (1994).

[22] An important issue for marine reserve managers is to conserve those characteristics that are "valued." Managers might want to measure diversity across several different types of characteristics.

[23] It is even possible to incorporate species richness into the diversity measures (Solow, Polasky, and Broadus 1993).

[24] The authors focus on reductions in biological diversity from extinction. Salm and Clark (1984) argue that in the marine environment the problems of biological diversity relate more to intraspecific genetic impoverishment than to extinction events. In theory, the methods referred to here could be applied to intraspecific problems.

[25] The use of the term *option value* in this context is slightly different from that described in Chapter Two, *Nonmarket Measures of Benefits and Costs* above. Here, option value is taken to mean the expected future benefits from preservation of alternative sets of species without any explicit reference to conditions leading to a willingness to pay risk premiums.

[26] This is like placing an additional constraint in the model that requires certain species to be in the set that is selected.

3 Benefits Transfer Issues

The lack of information on nonmarket benefits for most marine areas and resources hinders our ability to create and manage marine reserves efficiently. Environmental economists have begun to focus on the concept of "benefits transfer" or the use of nonmarket valuation models or results developed for one area or resource in another area or for other resources (Brookshire and Neill 1992).[1] If benefit information can be transferred, considerable costs might be saved in decisions about the designation or management of a marine reserve. However, benefits transfer exercises run into the deep problem in environmental economics of "model uncertainty" as one source of uncertainty in welfare analysis (Freeman 1993a).

Some analysts have suggested the potential applicability of their valuation models in other locations (Hodgson and Dixon 1992; Edwards 1991; Bennett 1984), but, for the most part, this topic has been ignored by those who have conducted net benefit evaluations of marine reserves. Barton (1994) cautions against the ad hoc comparison of results from different areas (see Tables B.1, B.2, and B.3 in Annex B) because of variable methods, units, socioeconomic characteristics, and development contexts. Tables 3a and 3b, described above, are a type of comparison, although we have attempted to rescale the benefits estimates to make them more comparable and to represent some limited information about modelling approaches and socioeconomic measures.

The results of a recent valuation study of a land-based reserve, the Monteverde Cloud Forest Preserve in Costa Rica (Table 3a), may have some implications for the extent to which benefits can be transferred legitimately from developed to developing countries (Echeverría, Hanrahan and Solórzano 1995). Employing contingent valuation techniques to estimate *one-time* lump sum WTP for preservation, the authors found that, even with lower incomes on average, Costa Ricans valued the reserve more highly ($149) than did non-Costa Ricans ($129), who were mostly from the United States.[2] Although their results may deserve further investigation, the authors believe that Costa Ricans respond differently to contingent valuation questions than do non-Costa Ricans.

In general, three key criteria must be satisfied for nonmarket benefit models or estimates to be transferred validly from one study area to another (Boyle and Bergstrom 1992). First, the resources and resource quality conditions should be similar at the two areas. Second, the socioeconomic characteristics of the relevant populations should be similar in the two areas. Third, the specific nonmarket valuation methodologies, models, and estimation techniques used at the studied site should be the same as those that would be applied at the site in question, given sufficient management resources. Tables B.4 and B.5 (Annex B) from Leeworthy (1991) give a sense of the range of different values obtained from the use of different estimation techniques at the *same site.*

Typically, one or more of the above criteria are not met because site attributes differ. We might expect this problem to be particularly acute in the case of marine reserves because reserves often are selected for designation on the basis of *unique* resources or features. To the extent that these criteria are not met, benefits transfer efforts will result in biases. Some analysts have argued for the use of "multipliers" to correct for these potential biases, but this ad hoc practice encounters the same sorts of problems attributed to the scoring methods discussed earlier. Loomis (1992) argues for the transfer of models, not estimates, to reduce the potential for biases.

In order to increase the reliability of benefit transfers, existing and future studies might be specially designed. Desvousges, Naughton and Parsons (1992) recommend four design features. First, multisite models, which focus on substitute and complementary choices, should be employed. Second, they recommend comparisons of identically structured multisite models at different locations. Third, the models should investigate variables that are important to policymakers. Fourth, the variables used in the models should be available in areas to where the results are to be transferred. These criteria, and others, are likely to be the rudiments of a "systematic protocol" for benefit transfer analysis called for by Smith (1992) and others.

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1 Benefits transfer issues also may arise in the use of nonmarket valuation results from one site at different points in time.

2 As can be seen in Table 3a, this pattern was also observed for the Great Barrier Reef Marine Park (Hundloe 1989). On the other hand, Kaoru and Broadus (1994) observed that tourists to Wellfleet value preservation of the harbor more than the residents. These differences need to be explored in greater depth, but they may arise due to differences in patterns of actual or implied property rights, socioeconomic characteristics, survey design and administration, among others.

4 Pricing and Access

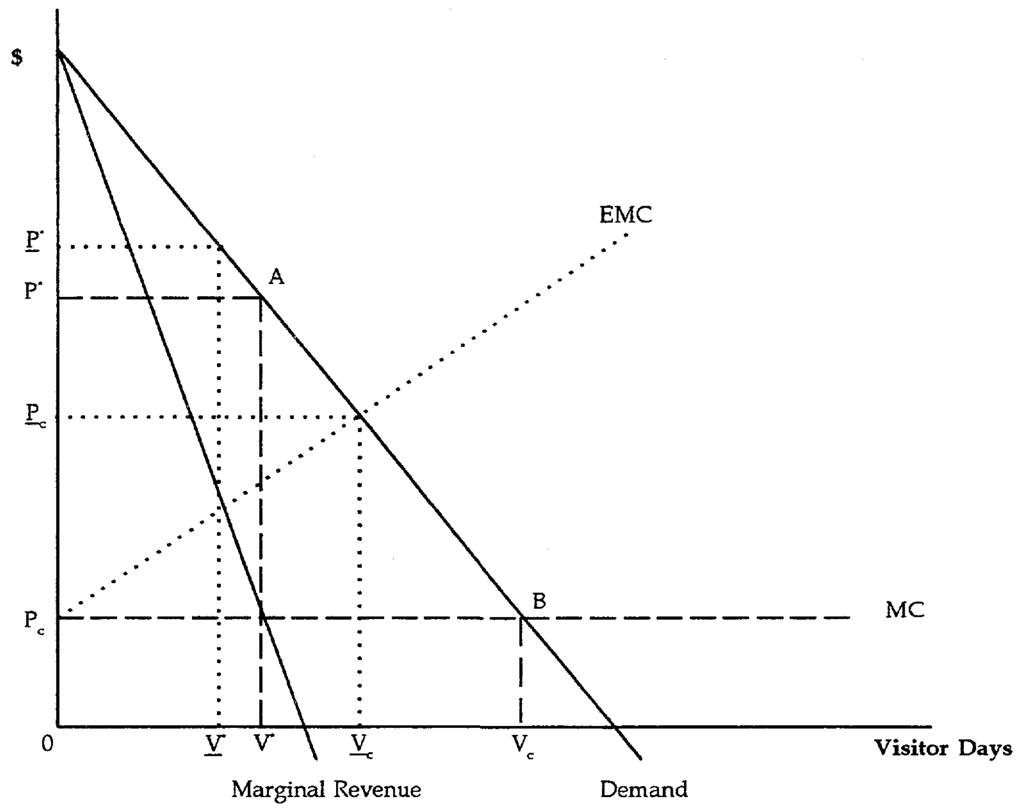
Controlling access to marine reserves is considered important in some situations to prevent overuse of the resource. Charging entrance or user fees ("pricing") and issuing permits are two ways of controlling access. A side-advantage of pricing techniques, but not permits, is that they can raise revenues that might be used to manage the reserve, to pay compensation, or to repair damages to natural resources or infrastructure.[1] Geoghegan (1994) has shown that pricing is one of many categories of potential funding mechanisms for a marine reserve (Table C.1 in Annex C).

Because marine reserves tend to be designated in areas that have been determined to have unique or rare ecological, cultural, or geographical characteristics, we expect that demand for the environmental "service" provided by a marine reserve is inelastic. In some ways, it seems natural to consider environmental services as products that might be sold to "consumers" or users of the resource. One way in which to "price" the reserve is to charge fees for entering the reserve or for using certain resources. Another way is to control entry into an industry that provides tourist services, such as boat trips for recreational fishing or whalewatching.

Some analysts have considered marine reserve use, especially tourism, to be consumptive in the sense of a nonrenewable resource, resulting in irreversible degradation through use, or in the sense of a renewable resource, resulting in reversible degradation (Dixon 1993a; Tisdell 1988). Because of their nature as quasi-public goods for which it is difficult to exclude users, there may be tendencies toward overuse of the resources of marine reserves. This phenomenon is most obvious in the cases of commercial or recreational fisheries and also for scuba diving. One way to look at entrance or user fees, therefore, is as market-based instruments for controlling overexploitation of the resource which should be set at the level of a *pigovian tax* (similar to an optimal pollution charge). Depending upon the nature of uncertainty over benefits and costs (Baumol and Oates 1988), these fees might be seen as a more efficient instrument than, say, a quota on tourist visits (Adar and Griffin 1976). Net benefit evaluation can play an important role in determining the optimal size of the tax.

Tisdell (1988), Lindberg (1990), and Broadus (1988) examine some of the theoretical issues associated with pricing in ecotourism markets. Broadus (1988) develops a model of *controlled-entry* pricing of a marine reserve. For a unique marine reserve with inelastic demand, as shown in Figure 5, the government might control entry into the market for the sale of tourism services. The effect of this control is to restrict the number of visitor days from V_c to V^*. If tourism results in external environmental costs, represented by the curve labelled EMC, then, in some cases, this policy leads to an outcome that is closer to optimal (V^* approaches $\underline{V}^*$). Another benefit of such a policy is that it may lower demand-contracting congestion effects. From a dynamic perspective, it may be optimal to allow slightly more than V^* visitor days because of a *recommendation* effect.[2] Visitors may be more likely to return in the future, and to recom-

Figure 5
Comparision of open-entry on the equilibrium number of tourist visits, price, and revenue



This figure also demonstrates how controlled-access can lead to an outcome nearer the "optimal" outcome when the costs of environmental damages resulting from tourist visits are taken into account.

Source: Broadus (1998)

mend the experience to others, if they retain larger consumers' surpluses.

Lindberg (1990) develops a two-tier pricing model that discriminates between residents and foreigners, charging separate prices for each. To implement the model, demand should be estimated separately for each group, and pricing set through controlled entry policies that may differ for each group. Lindberg argues that governments should maximize resource rents from a reserve, and then plow these rents back into the reserve and into surrounding communities to enhance the possibilities for sustainable development. Along these same lines, Edwards (1991) estimates the demand by foreign tourists for vacations to the Galapagos Islands and

Marine Resource Reserve and then calculates a tax to maximize the resource rent, subject to a tourist "carrying capacity" constraint.

In 1992, the U.S. Congress requested that NOAA examine the feasibility of user fees for U.S. national marine sanctuaries. Table C.2 (Annex C) lists some of the relevant characteristics and considerations for implementing user fees in U.S. marine sanctuaries. NOAA concluded that: (1) entrance fees were considered impractical because of difficulties in controlling access to a marine reserve; (2) users do not support user fees unless the revenues are returned to the site where collected and are used to provide services and facilities to the groups from which they were collected; (3) types and amounts of user fees should be sanctuary specific; (4) because of jurisdictional overlaps, user fees at a national marine sanctuary cannot be a unilateral federal action; and (5) the goods and services to be provided must be clearly specified in CVM surveys in order to obtain meaningful estimates of WTP user fees. As indicated in these conclusions, economic evaluation has a useful role to play in the determination of user fees.[3]

Under either a pricing or a permitting policy, some poaching may occur. As a result, monitoring and enforcement may be important but costly aspects of the management of a marine reserve. We have found no studies that have investigated enforcement approaches to control poaching of marine reserves. Chaloupka (1987) applies a randomized response survey design to estimate the degree of noncompliance with shell-collecting permits in the Great Barrier Reef Marine Park. The author finds low levels of noncompliance with requirements to obtain a permit but high levels of noncompliance with specific permit conditions. Milner-Gulland and Leader-Williams (1992) examine reserve enforcement strategies using a model of poaching incentives applied to four national parks and seven game management areas in Zambia's Luangwa Valley.

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[1] However, there is no reason why these revenues should not be spent on other important public purposes.

[2] Over time, the "optimal" number of visitor days will depend upon tradeoffs between environmental effects, congestion effects, and recommendation effects.

[3] The Clinton Administration's 1996 appropriation request for U.S. national marine sanctuaries program ($12 million) eliminates a requirement to collect user fees to offset the program's budget. User fees may be instituted to supplement the budget.

5 Issues of Design and Distribution

Reserve Area Design Issues

The discussion thus far has focused on whether or not net benefits exist to the creation and management of a marine reserve. We now examine the issues of reserve size, reserve shape, and the possibility of multiple zoning restrictions.

Irland (1979) presents a "systematic approach" to the creation of a reserve (Figure D.1, Annex D). This kind of a checklist is useful in characterizing what needs to be done to design a marine reserve, but it is not of much help in identifying specific design features.

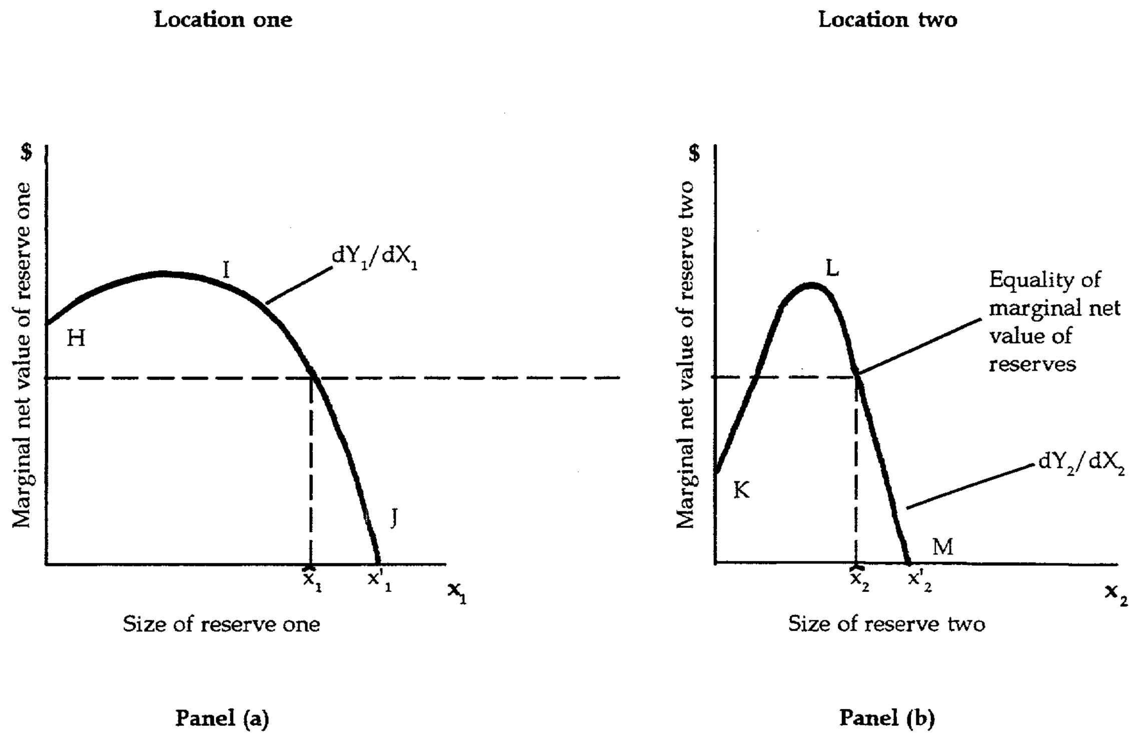
Tisdell and Broadus (1989) consider the optimal size of a marine reserve, holding constant issues such as variations in resource use regulations. The authors model the total benefits and total costs of a marine reserve as a function of its size. Optimal size is determined as the point where total *net* benefits are maximized. Repetto and Solow (1991) use this approach to simulate how the size of the Salt River Bay Reserve in the U.S. Virgin Islands might be determined. They model total benefits as a function of the expected number of species preserved in the reserve, where the probability that a species is preserved depends upon the number of individuals from that population in the reserve. The number of individuals in the reserve, in turn, depends probabilistically upon the size of the reserve.

Tisdell and Broadus (1989) also consider a situation in which the combined area of reserves is constrained. This situation might arise if other uses of ocean areas, such as vessel traffic lanes or energy production regions, have a higher priority. The optimal size for each reserve is found by equating marginal net benefits at each location (Figure 6). The authors note that these models are simplifications; in practice, models will require net benefit estimation and the potential need to design reserves according to complex biogeographical patterns.

Another dimension affecting reserve design is the stringency of zoning restrictions. If marine resource use regulations can be conceptualized as a continuum, then, in theory, we would want to set regulations such that the marginal benefits from an incremental tightening of the regulations equate with the marginal costs (lost opportunities, increased enforcement). In practice, variations in regulation are reflected in multiple zoning approaches. Salm and Clark (1984) present schematic diagrams of what they describe as "core-buffer" zone design (Figure 7, panels a and b). Such a design was incorporated into a recommendation to the Ecuadorian government for a marine reserve around the Galapagos Islands (Broadus and Gaines 1987; Broadus et al. 1984).

Larger reserves with complex biogeographies can have many different kinds of zones, representing different resource regimes. Such designs are exemplified by the Great Barrier Reef Marine Park in Australia (Figure E.1, Annex E) and the Florida Keys National Marine Sanctuary in the United States (Figure E.2, Annex E). In these two cases, net benefit evaluations played no role in determining reserve size or internal zoning patterns. Cocks (1984) describes the "SIRO-PLAN" approach to zoning on the Great Barrier Reef. This ap-

Figure 6
Use of marginal net benefit analysis to determne the optimal size of marine reserves when the overall area available of such reserves is limited.



Source: Tisdell and Broadus, 1989. Reprinted with the permission of Taylor & Francis, Inc., Washington, DC. All rights reserved.

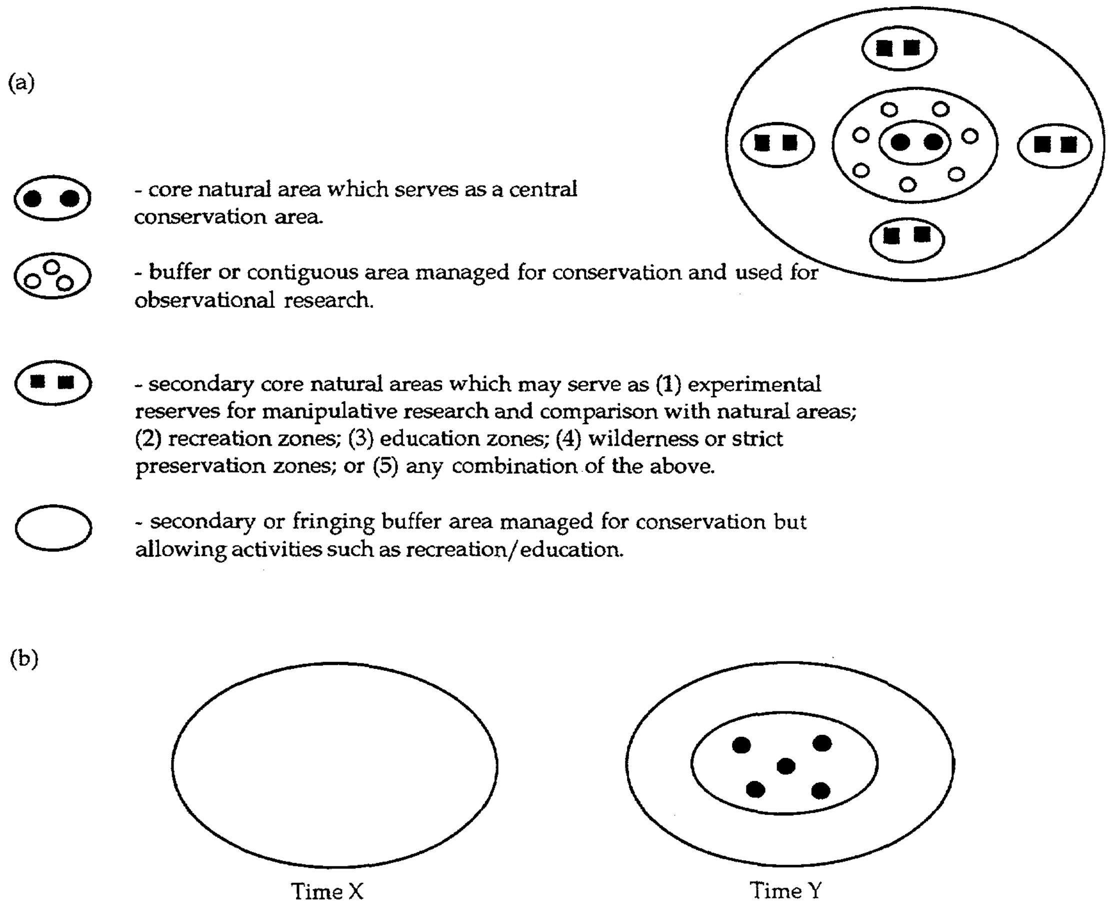
proach is a form of arbitrated negotiation among interest groups, which we describe further in Chapter Five, *Distributional Considerations*. Ehler (1994) describes an "integrated, continuous management process" for the Florida Keys sanctuary, which may be related to the SIRO-PLAN process, but the author does not mention net benefit evaluation as an input into the decisionmaking process.

Distributional Considerations

Distributional and equity issues are generally considered to be beyond the pale of welfare economics. However, Tisdell (1991:137) notes that net benefit evaluation "... may not be effective in conflict resolution, if the compensation of losers is purely hypothetical." As policy analysts, advocates of the evaluation of net benefits should be aware of opportunities for achieving efficient resource allocations through effective redistributional techniques, such as payment of compensation.

Rettig (1994) has outlined the benefits of compensation under conditions of uncertainty about whether or not the legal regime affecting the investments of property owners will change.

Figure 7
Schematic representation of zoning in a marine reserve:
(a) discontinuous core areas connected by buffers; (b) migrating or periodic core areas.



Source: Salm and Clark, 1984. Reprinted with the permission of the International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Five general advantages to compensation may exist: (1) it may force government to consider more carefully the opportunity costs of its actions; (2) it may reduce the cost of changing legal rules; (3) it may lead to "better" rules in the sense of acceptance and cooperation among the relevant interests; (4) it may reduce transaction costs in the long-run; and (5) it is often consistent with widely held social norms or presumptions of entitlements to resource use. These advantages are lessened to the extent that compensation creates a moral hazard, attracting investments that would not be made in its absence.

When considering distributional questions, issues arise about the effects of marine reserve designations or management actions on the implied or actual property rights that individuals may hold. If the actual compensation of losers by gainers is a policy objective, then initial property right distributions will affect the selection of the most appropriate welfare measure and therefore, potentially, the size of net benefits. Freeman (1993a) is the best recent survey of the issues surrounding the definition and measurement of welfare changes. In the specific context of a marine reserve designation, Doeleman (1991) explains qualitatively how differences in WTP and willingness-to-accept (WTA) compensation may depend upon the marginal utility of an individual's income.

We take the perspective that the citizens of a country in which the reserve is located are the "owners" of, or at least have jurisdiction over, the ocean area that is under consideration for marine reserve status.[1] We ignore tricky jurisdictional issues across countries or domestic levels of government, which, in any case, present only legal issues. We assume that the government, as agent, should seek to maximize the present value of net benefits from the use of the ocean area for the principal, its citizens. We assume, as well, that the optimal way in which to accomplish this task is to create a marine reserve in which the most valuable uses, or nonuses, are permitted and other noncompatible uses are excluded.

If the marine area was not being used prior to the designation, then, by definition, there are no losers from protecting the area as a marine reserve. If there were *permitted* uses of the area's resources, such as for offshore energy exploration or commercial fishing, then these users will have no "legal" use rights beyond the period for which permission was granted by the government. If these users had permanent rights granted by the government (for example, rights to navigate or rights of indigenous peoples to harvest marine mammals or fish stocks) or if rights of shorter duration are revoked prematurely, then these users are clearly "losers".[2] The appropriate welfare measure of opportunity costs is how much these users are willing to accept compensation (see Freeman 1993a). To the extent that the displacement of these prior uses involves an opening up of the resource for new and different users, or nonusers, then they are clearly "gainers," and the appropriate welfare measure of benefits is their willingness to pay for the right to use the resource.

In general, laws provide for compensation to holders of property rights that are revoked.[3] New users often are not required to spend their consumer surpluses, although user fees, discussed in Chapter Four, may be interpreted as a form of compensation to the resource "owner" that captures a portion of these consumer surpluses. Economic evaluation can clearly play a role in measuring the size of compensation payments.

Rettig (1994) identifies another issue that may have great importance as a source of conflict. Some users may believe that if the government has traditionally condoned, or perhaps even encouraged, the use of a resource, then they have been awarded "implied" property rights to the resource. An example might be an annual license for commercial fishing. If licenses have always been awarded in the past, perhaps primarily for accounting purposes, fishers may expect that licenses will always be issued in the future. Even if the law is completely clear, interpretation and traditional practice may become a source of conflict, thereby imposing costs on society to resolve the conflict.

The "SIRO-PLAN" developed for the Great Barrier Reef has potential for dealing with issues such as user presumptions of implied rights. SIRO-PLAN is an iterative negotiation process among interest groups, assisted by a negotiation facilitator, to develop a mutually agreed upon approach to marine reserve zoning. An outline of the approach is presented in Figure D.2 (Annex D), from Cocks (1984). In critiquing SIRO-PLAN, Tisdell and Broadus (1989:49) explain that:

> The problem of zoning the GBRMP cannot be solved by backroom optimization procedures even though such procedures could conceivably be used to draw up draft plans.... [SIRO-PLAN] is not an optimization procedure but a search and trial-and-error approach, which aims for a satisfactory solution. It has an important quality in view of the GBRMP legislation of allowing for adjustments for demands by interest groups. However, danger exists of this method becoming a way of justifying the opinion of the client whether that opinion is well based or not.

The integrated, continuous management process for the Florida Keys National Marine Sanctuary, described by Ehler (1994) and displayed in Figure D.3 (Annex D), shows similarities in terms of bringing different interests together to zone and manage a marine reserve. We note that decisionmaking by the different interests in such processes could be aided by net benefit evaluations, particularly those conducted by neutral analysts (cf., Sebenius 1984 for an example in the context of negotiation the third U.N. Convention on the Law of the Sea). Because of the obvious costs of implementing large-scale negotiations such as these, they may be warranted only in the case of large marine reserve designations, such as those for the Great Barrier Reef or the Florida Keys.

1 Coastal reserves may involve more complicated property regimes.

2 The extent to which this statement is true will depend, of course, on the nature of these rights and the restrictions on the exercise of these rights within the reserve.

3 The extent to which this statement is generally true depends critically, of course, upon the relevant jurisdiction.

6 Summary

In summary, we highlight the following points concerning the use of net benefit evaluation in the context of creating and managing marine reserves:

Net benefit evaluation is an important input into decisions about establishing, sizing, and zoning a marine reserve and regulating, monitoring, and enforcing uses of the reserve's resources. Where feasible, all economic benefits and costs should be taken into account, including nonmarket benefits and costs.

The application of net benefit evaluation techniques are becoming commonplace in environmental management. Where feasible, nonmarket valuation techniques should be employed to estimate "total" net benefits. Some nonmarket benefit estimation techniques, such as direct survey methods (CVM), should be used with care and supplemented, if possible, with estimates from indirect techniques (TCM, HDA).

As a crude first approximation, comparisons of market benefits and costs can be employed to aid decisionmaking for marine reserves. It should be noted that marginal decisions about issues such as reserve size will be difficult, if not impossible, to make in the absence of estimates of nonmarket benefits and costs. If resources are not available for estimating nonmarket benefits and costs, then the transfer of benefit information from other sites should be considered. As a last resort, qualitative estimates of benefits and costs may be useful.

The opportunities for benefits transfer will depend upon differences among the resources at the original and transfer sites, the models and methods that have been used in the past, and similarities in sociocultural characteristics between these sites. The fact that most marine reserves are created in areas that are considered to be ecologically unique suggests that benefit transfers will be problematic. More work is clearly needed before benefits transfer can be widely applied in this field.

As environmental and socioeconomic conditions change over time, net benefit evaluations should be updated. Although we expect that, in most cases, it will be unlikely that designations will be reversed by new information, periodic economic re-evaluation can be a useful input into the dynamic management of the resources of a reserve.

Where conflicts arise over the uses of the resources in a marine area under consideration for reserve status or subsequent to its designation as a reserve, negotiation techniques (e.g., SIROPLAN or variations thereof) can be important to conflict resolution. Economic evaluation can provide important inputs into a negotiation process. Payment of compensation may be an important instrument in conflict resolution, particularly in cases in which a "presumption of implied rights" to resource use exists. Again, net benefit evaluation is relevant to determining the size of compensation payments.

Economic analysis is extremely important as an input in decisions about how to "price" the resource to manage tourist uses. User fees are one way in which to regulate a potentially degrading use of the resource. To the extent that user fees capture resource rents, they can be seen as a component of "sustainable" resource use. Revenues raised through the exaction of user fees can be used to maintain the quality of the resource or to improve conditions elsewhere in the relevant country.

One source of benefits through the establishment of a marine reserve is the value of information gained from delaying irreversible development decisions. However, we emphasize that the designation of a reserve itself represents another kind of irreversible decision (or reversible at some significant cost). For example, if offshore energy exploration is prohibited in a marine reserve, then the opportunity to gain information about a potentially valuable marine resource may be foreclosed. This kind of irreversibility should be incorporated as a cost of reserve designation.

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Annex A: Methods for Setting Priorities and Ranking

The following tables show methods for setting priorities, ranking uses, and determining compatible uses within a marine reserve. These methods do not explicitly use net benefit evaluation methods, but they might be usefully employed in combination with such methods.

Table A.1

Categories of protected areas and corresponding conservation objectives. Source: Salm and Clark (1984).

Table A.2

Conceivable uses and use-compatibility matrix for a hypothetical mangrove area. Source: Polunin (1990).

Table A.3

Major types of regulated areas and their use rules in the Great Barrier Reef Marine Park. Source: Polunin (1990), adapted from Cocks (1984).

Table A.4

Management options and techniques for marine reserves. Source: Foster and LeMay (1989).

Table A.5

Hypothetical "multipliers" for the aggregation of economic values of a marine reserve. Source: Spurgeon (1992).

Table A.6

Scoring method for determining tourism and conservation "values" in a marine reserve. Source: Salm and Clark (1984).

Table A.1
Categories of protected areas and corresponding conservation objectives

Primary Conservation Objectives	Strict Reserve I	National Park II	Monument/Landmark III	Managed Reserve IV	Protected Landscape/Seascape V	Resources Reserve VI	Anthropological Reserve VII	Multiple Use Area VIII	Biosphere Reserve IX	World Heritage Site X
Maintain sample ecosystems in natural state	1	1	1	1	2	3	1	2	1	1
Maintain ecological diversity and environmental regulation	3	1	1	2	2	2	1	2	1	1
Conserve genetic resources	1	1	1	1	2	2	1	3	1	1
Provide education, research, and environmental monitoring	1	2	1	1	2	3	2	2	1	1
Conserve watershed condition	3	3	3	3	2	3	3	3	3	3
Control erosion, sediment; protect downstream investments	3	3	3	3	3	3	3	3	3	3
Produce protein and animal products from wildlife; permit sport hunting and fishing			2		3	3	3	1	3	
Provide recreation and tourism services		1	2	3	1		3	1	3	
Produce timber, forage, or marine products on sustained yield basis				3	2		3	1	3	
Protect sites and objects of cultural, historical, and archaeological heritage		1	3		1	3	1	3	2	1
Protect scenic beauty and open space	3	1	2	2	1			3	2	1
Maintain open options; manage flexibly; permit multiple use					3			3	2	1
Stimulate rational, sustainable use of marginal areas and rural development	2	1	2	2	1	3	2	1	2	2

Note:
1 = Primary objective for management of area and resources;
2 = Not necessarily primary, but always included as an important objective;
3 = Included as an objective where applicable and whenever resources and other management objectives permit.

Source: Salm and Clark, 1984. Reprinted with permission of International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Table A.2
Conceivable uses and use-compatibility matrix for a hypothetical mangrove area

i) Major uses:

A. Wood production
B. Firewood and other subsistence gathering
C. Fish-pond conversion
D. Salt-farm conversion
E. Land reclamation for agriculture/forestry/building
F. Capture fisheries
G. Aesthetics/preservation/education
H. Prevention of erosion
I. Sewage processing/water quality control

ii) Compatibility matrix*:

	A	B	C	D	E	F	G	H	I
A	_	2	1	0	0	2	2	2	2
B		_	0	0	0	2	1	2	1
C			_	1	1	0	0	0	0
D				_	1	0	0	0	0
E					_	0	0	0	0
F						_	2	3	2
G							_	3	2
H								_	3
I									_

*Key:
0 no compatibility
1 low compatibility
2 some potential compatibility
3 high compatibility possible

Source: Polunin, 1990. Reprinted with permission of Harwood Academic Publishers, GmbH, Langhore, PA.

Table A.3
Major types of regulated areas and their use rules in the Great Barrier Reef Marine Park

i) Zone types:

PR = Preservation
SR = Scientific Research
MNP(B) = Marine National Park (B)
MNP(A) = Marine National Park (A)
GU(B) = General Use (B)
GU(A) = General Use (A)

ii) Activities allowed, forbidden, and subject to consent in the various zones:

			Zone types#			
Activities	PR	SR	MNP (B)	MNP (A)	GU (B)	GU (A)
Non-manipulative research	P	P	P	P	P	*
Research station activities	X	P	P	P	P	P
Manipulative research	X	P	P	P	P	*
Private power boats and day cruise vessels	X	X	*	*	*	*
Recreation activities (not fishing)	X	X	*	*	*	*
Tourist ships	X	X	X	P	P	*
Observatory structure/erection	X	X	X	P	P	P
Netting	X	X	X	P	*	*
Recreational fishing	X	X	X	*	*	*
Other line fishing	X	X	X	X	*	*
Trolling	X	X	X	X	*	*
Spear fishing	X	X	X	X	*	*
Collecting coral, shells, fish	X	X	X	X	X	P
Non-tourist ships	X	X	X	X	X	*
Trawl fishing	X	X	X	X	X	*

Controls
* = Allowed
X = Forbidden
P = Subject to consent and permit

Source: Polunin, 1990. Reprinted with permission of Harwood Academic Publishers, GmbH, Langhore, PA.

Table A.4
Management options and techniques for marine reserves

Options	Examples
Natural Resources:	
1. Zoning	Scientific Research Zone (GBRMP, Australia) Wilderness zone (Pulau Seribu, Indonesia) Forereef Zone (Looe Key, U.S.)
2. Activity Permits	Permits for seabed construction Mariculture permits Permits for manipulative research
3. Periodic Closure	Prohibited access during breeding season
4. Catch Limits	Protected species Minimum size limits Limits on recreational catch
5. Equipment Prohibitions	Prohibitions on wire traps and spearfishing Prohibitions on gill nets and trawling
6. Impact Limitations	Mandatory use of mooring buoys No discharge regulations Oil spill contingency measures
Submerged Cultural Resources:	
1. Documentation	Underwater photography and mapping Engineering drawings
2. Recovery and Preservation	Controlled salvage operations with permits

Source: Foster and LeMay, 1989.

Table A.5
Hypothetical "multipliers" for the aggregation of economic values of a marine reserve

	Economic use zones					
	Preservation	Tourism	Multi use	Sust. Extr.	Matriculture	Non. Sust.
Financial benefits						
Direct uses						
Fisheries	0	0	m	1	>1	0
Aquarium trade	0	0	m	1	s	0
Curio trade	0	0	m	1	s	0
Pharmaceutical	0	0	m	1	s	0
Other industrial	0	0	m	1	s	0
Genetic material	0	0	m	1	s	0
Construction	0	0	s	1	s	>1
Tourism	s	1	m	s	s	0
Research	1	m	m	m	m	s
Social benefits						
Indirect uses						
Biological support	1	m	m	m	s	0
Coastal zone ext.	1	1	1	1	1	0
Physical protection	1	1	1	1	1	0
Global life support	1	1	1	1	1	0
Social services	0	0	m	1	s	0
Indirect costs						
Navigational	-1	-1	-1	-1	-1	0
Other economic value						
Uses						
Product consumer surplus	0	0	m	1	s	0
Tourism consumer surplus	s	1	m	s	s	0
Social value	0	s	1	1	s	0
Research value	1	m	m	m	m	s
Educational value	s	1	m	s	s	0
Non-uses						
Option value	1	m	s	s	s	0
Existence value	1	s	s	s	s	0
Intrinsic value	1	1	m	m	m	0

This illustrates the different proportions of each use and non-use value which could be added together in different reef use zones to give the Total Economic Value of a reef system. The relevant proportions for each value are indicated here as multipliers which are further explained in the text.

Proportion of value which can be summed for each zone:
- 1 = full sustainable value
- >1 = increased value
- s = some of the value (0.01-0.50)
- m = most of the value (0.51-0.99)
- 0 = none of the value
- -1 = negative value

Source: Spurgeon, 1992. Reprinted with kind permission from Elsevier Science Ltd., The Boulevard, Langford Lane, Kidlington, 0X5 1GB, UK.

Table A.6
Scoring method for determining tourism and conservation "values" in a marine reserve

Tourism Value of Reefs of the Bunaken Islands Marine Park

Criterion	Nain	Bunaken	Mantehage	Siladen	Manado Tua
Aesthetics	1	2	0	1	1
Safety	2	1	2	1	2
Accessibility	0	2	1	1	2
Fishing activity	0	0	1	1	0
Total	3	5	4	4	5
Tourism value	43%	71%	57%	57%	71%

Note: "Aesthetics" implies a high percentage cover of living coral, large intact coral colonies, varied reef profile (dropoffs, caves, crevices), and clear water (0 = low, 1 = medium, 2 = high aesthetic appeal). "Safety" implies little or no wave action, no strong currents, and no chance of entanglement by nets or of proximity to explosives fishing (0 = low, 1 = medium, and 2 = high safety factor). "Accessibility" is measured as the distance from the mainland hotels and the ease of entry for divers from a boat (0 = low, 1 = medium, 2 = high accessibility score). "Level of fishing activity" is an estimate based on the distance from villages and the number of fishermen in villages fishing the area (0 = high and 1 = low level of fishing activity). "Tourism value" calculated as a percentage of the maximum potential score (=7).

Conservation Value of Reefs of the Bunaken Islands Marine Park

Criterion	Nain	Bunaken	Mantehage	Siladen	Manado Tua
Habitat variety	5	3	3	2	2
Unique coral habitat	1	0	1	0	1
Coral cover	1	2	1	2	1
Diversity	2	2	1	1	1
Intactness	1	0	1	1	0
Total	10	7	7	6	5
Conservation value	83%	58%	58%	50%	42%

Note: "Habitat variety" is the sum of each of the following habitats present: barrier reef, fringing reef, lagoonal reef, mangroves, sea grass beds (0 = absent and 1 = present). "Unique coral habitat" indicates the presence of a coral habitat not found elsewhere among the islands: Nain has fragile lagoonal coral colonies; Mantehage has coral assemblages in mangrove creeks; Manado Tua has unusual confluent mounds of *Euphyllia (Euphyllia)* and *E. (Fimbriaphyllia) ancora* covered by living corals (= less than 60%, 1 = 60-85%, and 2 = more than 85%). "Diversity" is the total number of coral genera recorded from the surface to a depth of 20 m (0 = fewer than 30, 1 = 30-40, and 2 = more than 40). "Intactness" is an estimate of the percentage of coral colonies that are broken between depths of about 2 m and 5 m (0 = more than 15% and 1 = 0-15% damaged coral). "Conservation value" calculated as the percentage of the maximum potential score (=13).

Source: Salm and Clark, 1984. Reprinted with permission of International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Annex B: Arrays of Estimated Economic Values

These tables demonstrate arrays of estimated economic values or economic impacts from the published literature. Representation of such values in the same table does not imply that the same kinds of economic modelling techniques have been employed or that the sampled populations have similar socioeconomic characteristics. Thus care should be taken in making comparisons among the locations or resources arrayed in these tables.

Table B.1

Examples of economic values placed on mangrove systems and mangrove ecosystem products. Source: Barton (1994), adapted from L.S. Hamilton and S.C. Snedaker, eds., Handbook for mangrove area management, United Nations Environment Programme and Environment and Policy Institute, East West Center, Honolulu, 1984.

Table B.2

Recent examples of economic values placed on tropical or sub-tropical wetland systems and wetland ecosystem products. Source: Barton (1994).

Table B.3

Comparisons of economic impacts of tourism in Caribbean marine and coastal protected areas. Source: Heyman (1988).

Table B.4

Consumer surplus per person per day for the John Pennekamp Coral Reef State Park. The results of the four models displayed in this table are from linear regression models using different combinations of potential determinant variables. This table is reproduced to demonstrate the potential variation in results at one site. The reader should refer to the original source for greater detail on model specifications. Source: Leeworthy (1991).

Table B.5

Consumer surplus per person per day for the John Pennekamp Coral Reef State Park. This table is reproduced to demonstrate the potential variation in results at one site. The reader should refer to the original source for greater detail on model specifications. Source: Leeworthy (1991).

Table B.1
Examples of economic values placed on mangrove ecosystem products

Type of Resource or Product	Location	Date	Value Placed on Resource (US $ per ha per year)
Complete mangrove ecosystem	Trinidad	1974	500
	Fiji	1976	950 - 1,250
	Puerto Rico	1973	1,550
Forestry Products	Trinidad	1974	70
	Indonesia	1978	10 - 20 (charcoal and wood chips)
	Malaysia	1980	25
	Thailand	1982	30 - 400
Fishery Products	Trinidad	1974	125
	Indonesia	1978	50
	Fiji	1976	640
	Queensland	1976	1,975
	Thailand	1982	30 - 100 (fish); 200 - 2,000 (shrimp)
Recreation, tourism	Trinidad	1974	200

Sources:
Fiji - calculated from information present in Baines (1979) and Lal (1983).
Indonesia - Peter R. Burbridge (Pers. COmm. 1983).
Malaysia - Tang et al. (1980).
Puerto Rico - Baines (1979).
Queensland - Baines (1979).
Thailand - FAO (1982).
Trinidad - Ramdial (1975) and Trinidad Div. of Forestry (1979).

Note: All of these estimates are approximate and are presented to give a range of values placed on mangrove ecosystem products. The values in each locale will vary.

Source: Barton, 1994.

Table B.2
Recent examples of economic values placed on tropical or sub-tropical wetland systems and wetland ecosystem products

Type of resource or product and location	Values placed on resource (US$/ha/yr)	Comment	Study
Complete wetland ecosystem:			
Philippines	6990	forestry, fishery and other products	World Bank (1989)
Forestry products:			
Fiji	9		Lal (1989)
Other wetlands products:			
Louisiana, USA	30	pelts	Costanza et. al. (1989)
Fishery/aquaculture:			
Louisiana, USA	63	commercial	Costanza et al. (1989)
Fiji	160	artisanal and commercial	Lal (1989)
Florida West, USA	88*	* marginal productivity value commercial	Bell (1989)
Thailand	24000-39000	resicual rent of oyster mudflats from e.g. nutrient flow from adjacent systems including mangrove	Baker and Kaeoniam (1986)
Recreation:			
Louisiana, USA	110	gross economic value (consumer surplus + expenditures)	Bergstrom (1990)
Florida West, USA	197	* marginal output of recreational services	Bell (1989)
Storm protection:			
Louisiana, USA	17 - 57		Farber (1987)
Louisiana, USA	317		Costanza et al. (1989)
Capturable biodiversity:			
Indonesia	1500	imputed from WTP surveys of international donors for rainforest conservation	Ruitenbeek (1992)
Enegy value:			
Louisiana, USA	1258 - 2093	*gross primary productivity value in fossil fuel equivalents	Costanza et al. (1989)

Note: values as reported of calculated to per hectare per year figures from information found in studies.

Source: Barton, 1994.

Table B.3
Comparisons of economic impacts of tourism in Caribbean marine and coastal protected areas

Area	Cash income generated/year (US $)	Benefit - Cost Ratio (Internal Rate of Return)	Visitation/year
Bonhaire Marine Park, Netherlands Antille	Divers spent 30,000,000 (estimated 1985)		85,000 dives/year (1976-1985)
Bahamas	Divers spent 80-90 million; % attributed to parks unknown (est. 1985)		
Biscayne National Park, Florida			578,000 visitors
British Virgin Islands parks	14,000,000		45,000 divers in Wreck of the Rhone Park
Buckoo Reef/Bon Accord Lagoon, Tobago	510,000		12,000 visitors
Buck Island National Monument, St. Croix			50,000 visitors
Cahuita National Park, Costa Rica		B/C: 9.5	100,000 visitors
Cozumel and Chankannaab Parks, Mexico			400-500 visitors/day in cruise ship season
Caroni Swamp National Park, Trinidad	2,000,000 (1974)		
Cayman Islands marine protected areas	Divers spent 53,200,000 (estimated 1985)		168,000 divers and snorkelers
Curacao Underwater park, Netherlands Antilles			2196 divers, 4060 dives; 30-40% in park (1986)
Everglades National Park, Florida			760,000 visitors
Key Largo National Marine Sanctuary, Florida			1,000,000 visitors
Monetgo Bay National Park, Jamaica	395,000 (projected)	IRR: 32% (projected)	96,000 visitors (projected)
Morrocoy National Park, Venezuela		B/C: 30.7 (projected)	1,500,000 visitors (estimated)
Pitons National Park, Saint Lucia	534,000 (projected)		116,000 visitors (projected)
John Pennekamp Coral Reef State Park, Florida			1,500,000 visitors
Saba Underwater Park, Netherlands Antilles	16,500 (1988)		2100 divers, 10,000 dives (estimated 1988)
Toboga Cays National Park, St. Vincent	350,000 (projected)	IRR: 14% (projected)	50,000 visitors (projected)
Virgin Islands National Park, St. Johns	23,400,000 (1980)	B/B: 11.1	750,000 visitors

Source: Heyman, 1988.

Table B.4
Consumer surplus per person per day for the John Pennekamp Coral Reef State Park

Method of Calculation				
Errors in Dependent Variable			**Omitted Variable**	
Model	**Mean ($)**	**Median ($)**	**Mean ($)**	**Median ($)**
Model 1	111.5	103.37	231.90	182.53
Model 2	124.08	118.34	261.21	248.26
Model 3	111.68	103.82	247.68	194.76
Model 4	135.80	130.62	304.44	285.15

a. Consumer Surplus Per Person Per Day is calculated using the following:

$$CS=\left[\frac{(Trips)^2}{-2\beta \cdot Q4 \cdot PEOPLE2}\right] \cdot \left[\frac{1}{1+\frac{1}{(t)^2}}\right]$$

where β = the estimated travel cost coefficient and (t) is the t-value on the estimated travel cost coefficient. The latter term in brackets is a correction factor for bias in consumer surplus. See Zellner and Park (1979) for the derivation of the correction factor.

b. Assumes the dominant source of error is measurement of the dependent variable trips. Sample means for Q4 and PEOPLE2 and the mean and median of the predicted number of TRIPS are used to calculate consumer surplus.

c. Assumes the dominant source of error is omitted variables. Consumer surplus per person per day is calculated for each individual in the sample using the observed number of TRIPS, Q4, and PEOPLE2 for each individual.

Source: Leeworthy, 1991.

Table B.5
Consumer surplus per person per day for the John Pennekamp Coral Reef State Park

		Method of Calculation				
		Errors in Dependent Variables:		Omitted Variables:		
Functional Form[b]	Model	Mean ($)	Median ($)	Mean ($)	Median ($)	Value of Time
Linear	5	202.89	190.08	454.48	425.69	1/3 of predicted wage rate
Linear	6	384.35	356.74	860.30	805.81	Full predicted wage rate
Semi-log	7	579.30	574.90	1,409.26	1,141.58	Zero
Semi-log	8	844.77	832.32	2,054.74	1,664.45	1/3 of predicted wage rate
Semi-log	9	1,591.08	1,567.35	3,869.29	3,134.36	Full predicted wage rate

a. Consumer Surplus Per Person Per Day for the linear model is calculated using the formula in Table 6, footnote a. For the semi-log model, the formula is:

$$CS = \left[\frac{\text{Trips}}{-\beta * Q4 * PEOPLE2}\right] \cdot \left[\frac{1}{1+\frac{1}{(t)^2}}\right]$$

where β = the estimated travel cost coefficient and (t) is the t-value on the estimated travel cost coefficient. The latter term in brackets is a correction factor for bias in consumer surplus. See Zellner and Park (1979) for the derivation of the correction factor.

b. The linear mkodel takes the form TRIPS = a + b*TC - c*AGE + d*AGESQ + e*PRIMARY + f*DSUBI and the semi-log model takes the form LTRIPS = a + b*TC - c*AGE + d*AGESQ + e*PRIMARY + f*DSUBI where a,b,c,d,e, and f are the estimated coefficients, TC is the relevant travel cost definition and for the semi-log model LTRIPS is the natural log of TRIPS.

Source: Leeworthy, 1991.

Annex C: Funding Mechanisms

Table C.1

Framework for selection of appropriate funding mechanisms. Source: Geoghegan (1994).

Table C.2

U.S. marine sanctuary use and users questionnaire. Source: Leeworthy (1993).

Table C.1
Framework for selection of appropriate funding mechanisms

Mechanism	Conditions required	Constraints
Government subvention:	Participation and lobbying in budgeting process. Encourages political interference.	Usually inadequate for full management.
International assistance agency:	Government request. Ongoing relationship or cooperative agreement.	Generally not available to NGOs. Usually not flexible: requires preparation of and adherence to project document. Can require use of foreign consultants.
Foundation grants:	Prospect research, initial inquiry, proposal submission, and follow-up.	Generally not available to governments. Usually not flexible requires preparation of and adherence to project document. Limited field of interest of most foundations.
Donations and membership associations:	Personnel and mechanisms for making requests and following-up.	Generally only available to NGOs.
User fees:	Provison of "valued" services. Personnel and system for collection. Legislation or regulation (sometimes).	System must be set up to assure that fees available to management agency; not returned to general fund.
Souvenir sales:	Retail outlets. Funding to manufacture sale items.	Can only be expected to provide small percentage of total revenue required; useful in conjuction with other mechanisms.
Concessions:	Sufficient market for services offered. Personnel and system for monitoring and collection. Infrastructure (usually).	Can be perceived as competition with existing businesses in area. Requires cost/ benefit analysis prior to implementation. Can result in pressure to exceed carrying capacity.
Debt swaps:	Discounted commercial debt for sale. Source of capitalization. Agreement of government. Involvement of experienced advisors.	Not worthwhile if debt discount minimal.
Trust funds:	Source of capitalization. Professional involvement in investment and management . Governing Board and management body.	Implementation and management require NGO or private sector involvement. Capitalism must be at least 10 times required annual income.
Nature tourism:	Attractions appealing to ecotourism market. Relationship with tour companies. Personnel and other support resources. Mechanisms for capturing portion of revenue.	Little initial return; follow-up required. Need to break into market; industry now focusing on other regions. Can result in pressure to exceed carrying capacity.

Source: Geoghegan, 1994. Reprinted with permission of International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Table C.2
U.S. marine sanctuary use and users questionnaire

Sanctuary	Total # of recreation users &/or user days	Activity	Number of recreation users &/or user days	Significant Expenditures (>$100,000)	Seasons	Comments on types of fees, special considerations (e.g. exemptions), and possible fees for activities conducted from shore
Flower Garden Banks	5475-7250	Scuba diving (*from ch. boats*)	3000-4000	No	April-October	Possible fees for charter boats by diver although divers not consumptive users; NOAA has no on-site presence; fees may hinder donations.
		Boating	100-200 boats/yr.	No	Peak in August	
		Charter Dive boats	Boat 1: 50 trips/yr. (2 days ea., 25-30 divers/trip) Boat 2: 10-15 trips/yr. Boat 3: 5 trips/yr.	No Peak in August	Peak in August	
Stellwagen Bank	Unknown	Whale watching/	Unknown	No	May-August	User fees unecessary at this time.
		bird watching/ fishing	Unknown	No	Late spring-early autumn	
Fagatele Bay		Picnickers/swimmers/ snorkelers	300-500/yr.	No	Unknown	In appropriate considering small number of users; difficulty assessing fees; relationship w/landowners.
	500	Divers/boaters	<100/yr.	No	Unknown	
		Rec. fisherman	0-100/yr.	No	Unknown	
Gray's Reef	4,500	Fishing	4,300	No	Year-round, summer peak	Site 17 mi. offshore, boat decal registration only practical fee; GA considering saltwater fishing license.
		Diving	200	No	Summer	
Gulf of the Farallones/ Cordell Bank	11,640,000	Beach walking/swimming	9,000,000	No	Year-round, peaks on holidays.	No response.
		Fishing vessels	1,000,000	No		
		Clamming/fishing	1,500,000	No		
		Snorkeling	100,000	No		
		Diving	20,000	No		
		Canoe/kayak	20,000	No		
Florida Keys	This sanctuary was only recently designated, therefore, this information is not yet available.			Recommend fees on boating, recreational fishing, scuba/snorkel diving.	Charter/party boats prefer annual fee to head count; no fees for onshore uses.	
Channel Islands	150,000	Airplane/boat charters	Unknown	No	Year-round	Concessions for commercial tour and charter operators, or general transit fe, only realistic fees; public views user fees as another unnecessary layer of bureaucracy unless NOAA can provide quantifiable results of additional resource protection.
		Boat rentals/instruction	Unknown	No	Summer/fall	
		Diving charters/instruction	Unknown	No	Summer	
		Fishing parties	Unknown	No	Summer	
		Whale watching	Unknown	No	Summer	
Hawaiian Islands Humpback Whale	Unknown	Boating/tour boat	Unknown	Unknown	Winter	No response
		Sport fishing	Unknown	Unknown	Year-round	
		Diving	Unknown	Unknown	Year-round	
		Research	Unknown	Unknown	Year round	
		Nature observation	Unknown	Unknown	Year-round	
		Snorkelling	Unknown	Unknown	Dec.-March	
MONITOR	200	Diving (research)	200	No	Year-round, summer/ early fall.	Current use limited to research activities; if use expanded, fee may be practical to offset cost of presence of NOAA representative.

1. All data are managers' estimates unless otherwise noted.
2. Information taken from: a. Marin Open Space Report; b. PR National Seashore - Annual Report; and c. Golden Gate National Recreation Area - Annual Report.
3. Information taken from: a. Reynolds, Julie A., "Commercial, Recreational Uses and Economic Benefits of the Channel Islands National Maarine Sanctuary," California Sea Grant Fellow, 1991; and b. The Channel Islands Monthly Public Use report.

Note: Information not yet available for the recently designated Monterey Bay National Marine Sanctuary.

Source: Leeworthy, 1993.

Annex D: Methods for Integrated Planning of Marine Reserves

Table D.1

A systematic approach to analyzing preservation decisions. Source: Irland (1979).

Table D.2

Steps in the SIRO-PLAN land use planning method. Source: Cocks (1984).

Table D.3

Components of the integrated, continuous management process for the Florida Keys national Marine Sanctuary. Source: Ehler (1994).

Table D.1
A systematic approach to analyzing preservation decisions

I. The right questions

A. Identify major objectives of preservation appropriate to the case in hand. Express any notable side-objectives. Is the purpose to conserve an endangered animal or plant? To preserve a unique recreational resource? To avoid downstream damage from logging or development?

B. Identify options. Set forth the options available for achieving the objectives, including:
1. alternative sizes and locations of land areas
2. regulatory requirements for included and nearby areas
3. acquiring more information, such as mineral surveys

II. Appraisal -- describing outcomes

A. Measure benefits in physical or biological terms, relative to stated objectives, for each option. Express benefits quantitatively, where possible, or indicate their nature in general terms as data allow.

B. Express in physical or biological units the known direct and opportunity costs of each option.

C. For all costs and benefits where appropriate, express in dollar values.

D. For both A and B, express as time streams, if relevant, accounting for expected future changes. If uncertainty exists as to the value of key variables, employ best available estimates and express in terms of means and ranges where possible.

E. Identify alternative sources of the benefits and opportunity costs reviewed in A and B.

III. Comparing options

A. Express benefits and costs in terms of present worth (PW) at a range of discount rates.

B. Compare PW(B) with PW(C) in terms of B/C or B - C. Display with qualitative descriptions of other major values at stake.

C. Assess local and national economic impacts of each defined option, if needed. Review possible mitigation measures, if needed.

D. Assess the impact of options on other values identified in the mandate for preservation or raised by affected parties to the decision. Present in brief narrative or tabular form.

IV. Analysis

A. Using explicit criteria, rank the options identified an summarize impacts of the recommended alternative, if one is selected.

B. Present a full summary of all above analyses in a form comprehensible to the interested parties and decisionmakers, identifying all value conflicts and controversies over data. Provide highly technical analyses as supporting appendixes. Summarize and evaluate major previous analyses of the same problem. Identify all known and suspected sources of bias in the data and assumptions employed in the analysis.

C. Subject the analysis to review by all interested parties. Analyze responses and make any required adjustments.

Source: Irland, 1979. Reprinted with permission of Lloyd C. Irland, Irland Group, Winthrop, Maine.

Table D.2
Steps in the SIRO-PLAN land use planning method

A. Establishing terms of reference and plan-making guidelines

1. Confirm the task as being within the class of planning exercises for which the procedure is designed.

2. Identify client, study area boundaries, relevant land uses, (or management regimes or controls), relevant interest groups and their demands, available land-use controls, and issues needing to be addressed.

3. Develop guidelines (policies) which suggest ways of zoning/managing various categories of land as sensible responses to the demands and issues being addressed.

4. Formulate measures of policy satisfaction which allow any zoning plan to be evaluated in terms of the extent to which it satisfies any particular policy.

B. Data collection and generation of plans

5. Subdivide study area into numerous mapping units which will be used
   a. as entities against which data will be collected and recorded
   b. as entities against which the plan will specify particular land-use controls

6. Collect data judged necessary to allow each measure of policy satisfaction to be calculated for any plan.

C. Evaluation of plans

7. Identify an initial reference plan (assignment of land uses/controls to mapping units) judged by the client to be feasible (not unacceptable) with respect to the extent to which it achieves each policy guideline.

8. In a direction suggested by the client, search for a plan which can be judged better than the reference plan in terms of policy achievement. If successful, designate this new plan as the new reference plan.

9. Repeat step 8 until time runs out or, as judged by the client, no further attempt should be made to improve the reference plan, i.e., the reference plan becomes the accepted plan.

D. Legitimation, implementation, and updating

10. Seek interest group objections and incorporate if client approves.

11. Allocate available resources to tasks required for plan implementation.

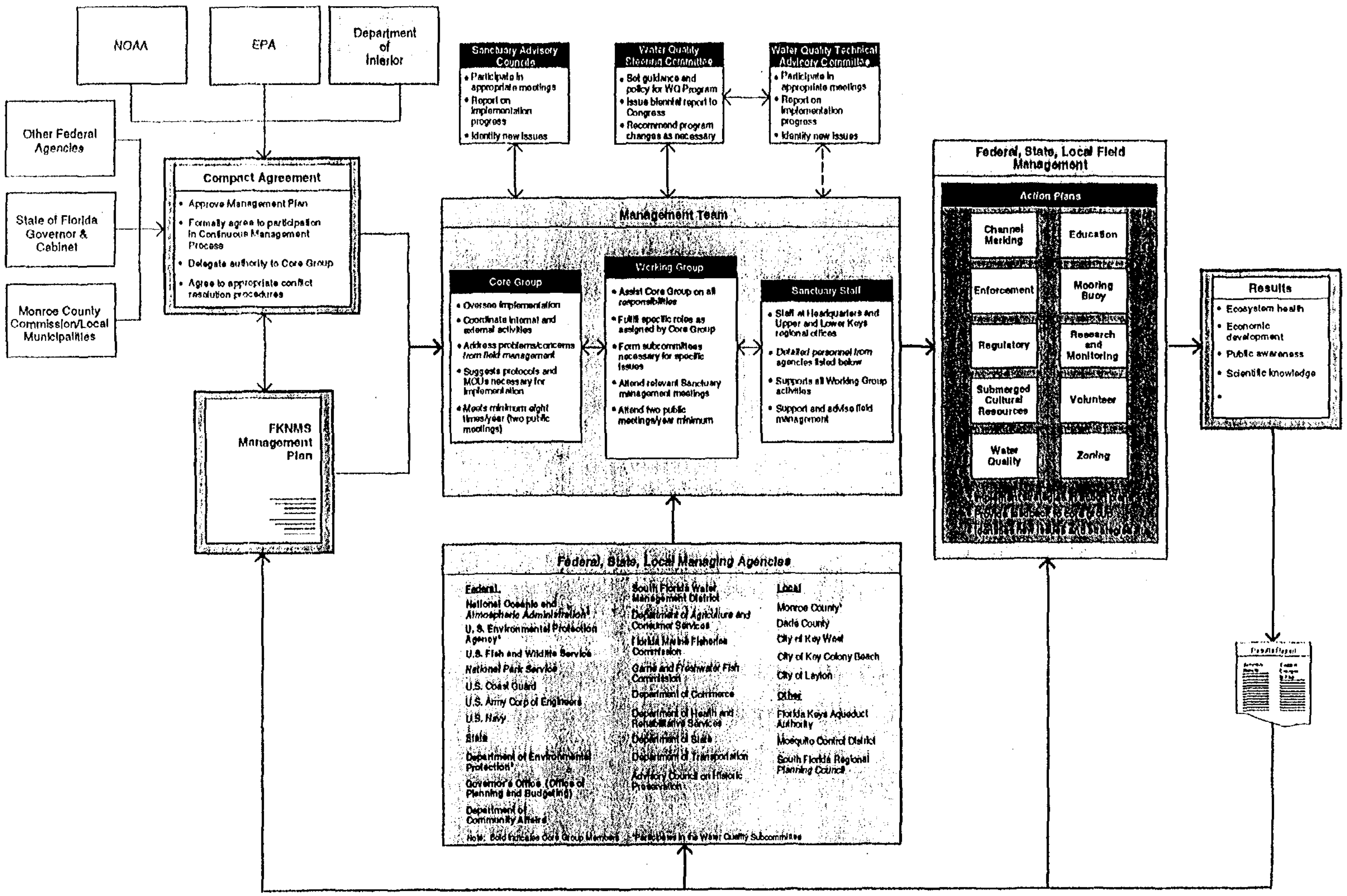
12. Monitor interest group demands and issues as basis for deciding when to revise plan.

13. Revise plan at intervals.

Source: Cocks, 1984. Reprinted with permission from Cocks, Taylor & Francis, Inc., Washington, DC. All rights reserved.

Table D.3

Components of the integrated, continuous management process for the Florida Keys National Marine Sanctuary



Source: Ehler, 1994.

Annex E: Multiple-Use Zoning Patterns for Two Marine Reserves

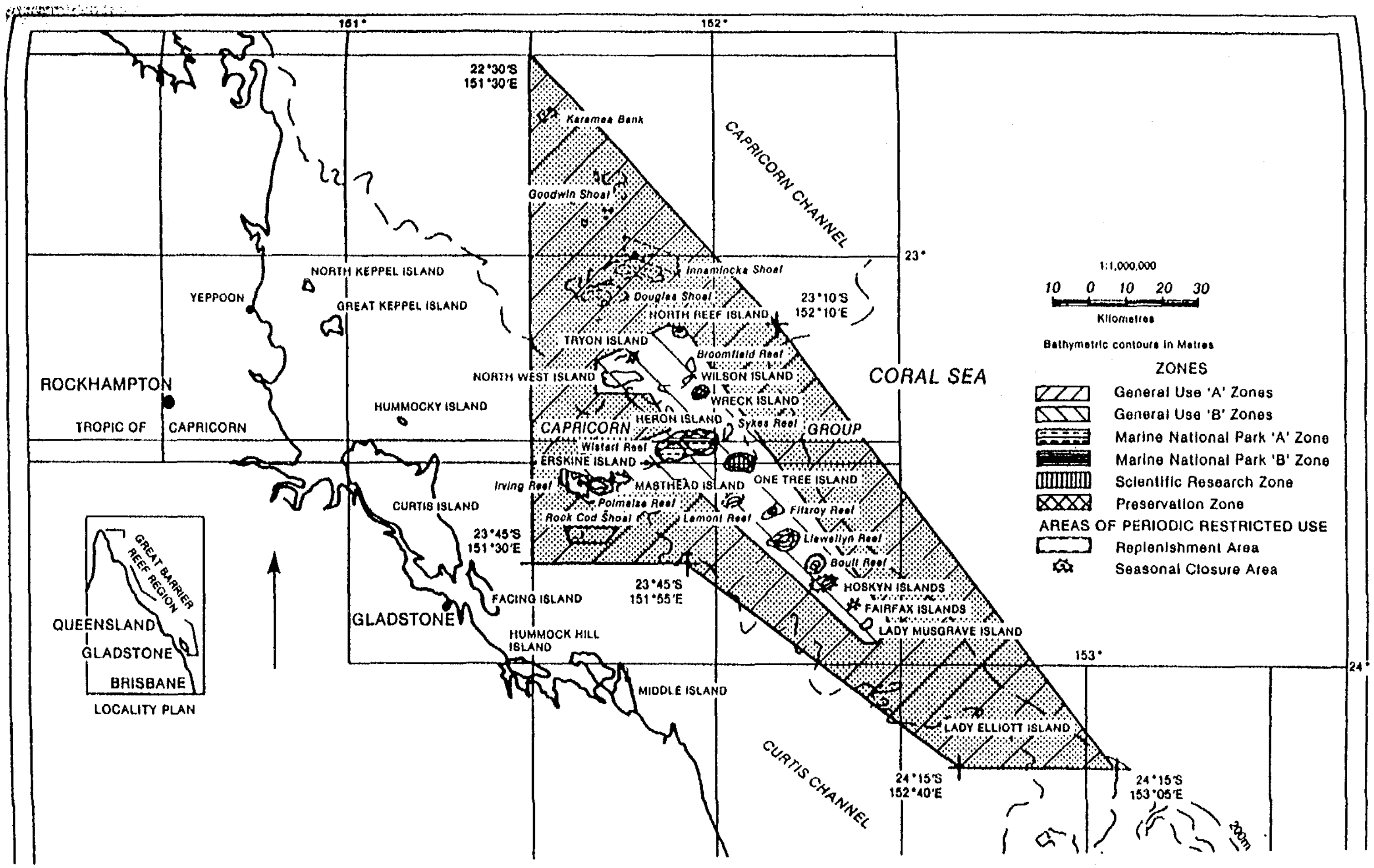
Figure E.1

Zoning plan for the Great Barrier Reef Marine Park, Capricornia Section. Source: Salm and Clark (1984), adapted from G. Kelleher and R. Kenchington, Australia's Great Barrier Reef Marine Park: making development compatible with conservation, In J.A. McNeely and K.R. Miller, eds., National Parks, Conservation, and Development: The Role of Protected Areas in Sustaining Society, Washington: Smithsonian Institution Press, 1984.

Figure E.2

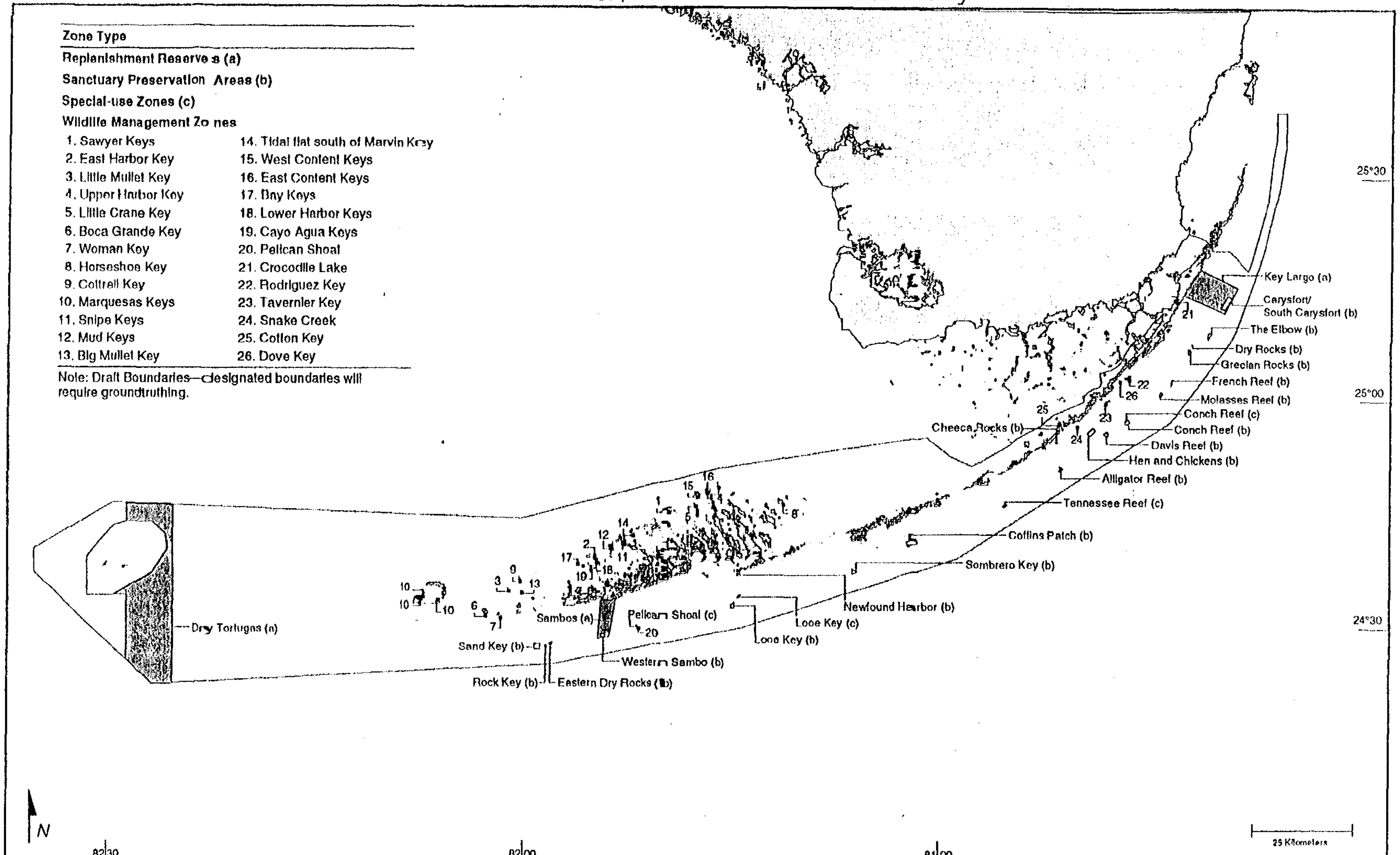
Replenishment reserves, sanctuary preservation areas, special-use zones, and wildlife management zones in the Florida Keys National Marine Sanctuary. Source: Ehler (1994).

Figure E.1
Zoning plan for the Great Barrier Reef Marine Park, Capricornia Section



Source: Salm and Clark, 1984. Reprinted with permission of International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Figure E.2
Replenishment reserves, sanctuary preservation areas, special-use zones, and wildlife management zones in the Florida Keys National Marine Sanctuary



Source: Ehler, 1994.

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