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Marine Pollution Prevention and Management in the East Asian Seas: A Benefit-Cost Framework

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MISSION STATEMENT

The primary objective of the Global Environment Facility/United Nations Development Programme/International Maritime Organization Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas is to support the efforts of the eleven (11) participating governments in the East Asian region to prevent and manage marine pollution at the national and subregional levels on a long-term and self-reliant basis. The 11 participating countries are: Brunei Darussalam, Cambodia, Democratic People's Republic of Korea, Indonesia, Malaysia, People's Republic of China, Republic of the Philippines, Republic of Korea, Singapore, Thailand and Vietnam. It is the Programme's vision that, through the concerted efforts of stakeholders to collectively address marine pollution arising from both land- and sea-based sources, adverse impacts of marine pollution can be prevented or minimized without compromising desired economic development.

The Programme framework is built upon innovative and effective schemes for marine pollution management, technical assistance in strategic maritime sectors of the region, and the identification and promotion of capability-building and investment opportunities for public agencies and the private sector. Specific Programme strategies are:

- Develop and demonstrate workable models on marine pollution reduction/prevention and risk management;
- Assist countries in developing the necessary legislation and technical capability to implement international conventions related to marine pollution;
- Strengthen institutional capacity to manage marine and coastal areas;
- Develop a regional network of stations for marine pollution monitoring;
- Promote public awareness on and participation in the prevention and abatement of marine pollution;
- Facilitate standardization and intercalibration of sampling and analytical techniques and environment impact assessment procedures; and
- Promote sustainable financing mechanisms for activities requiring long-term commitments.

The implementation of these strategies and activities will result in appropriate and effective policy, management and technological interventions at local, national and regional levels, contributing to the ultimate goal of reducing marine pollution in both coastal and international waters, over the longer term.

Dr. Chua Thia-Eng
Regional Programme Manager
GEF/UNDP/IMO Regional Programme
for the Prevention and Management
of Marine Pollution in the East Asian Seas

Contents

Contents

Acknowledgments

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Executive Summary

The coastal and marine natural resources of the East Asian Seas are of enormous value. Sea lanes and navigational channels benefit countries throughout the region and beyond. Mariculture, aquaculture and open-access fisheries are important sources of livelihood and food. Mangroves, peat marshes, seagrass beds and other ecosystems contribute to fishery stocks exploited throughout the region. Mangroves and peat marshes provide many other services, including the production of wood, charcoal and *in situ* harvests of fish and shellfish. They also protect coastal property and populations from flooding, storms and typhoons, act as sinks to reduce coastal pollution and sedimentation and lessen coastal erosion. Corals support fisheries used for recreational viewing and for consumption, and they protect shorelines from erosion and storms. Beaches and near shore water quality support recreation and tourism operations throughout much of the region.

However, sustainable use of the coastal and marine natural assets throughout the East Asian Seas are at risk (e.g., Cesar, 1996; Calow and Forbes, 1997). Coastal ecosystems, such as mangroves, have declined substantially, and are threatened by further loss from pollution and conversion to alternate uses. Pollution from agriculture, timber harvesting, domestic source and industrial activity has led to water and sediment quality problems, including excessive concentrations of *Escherichia coli* bacteria, pesticides and metals in some areas. This pollution threatens ecosystems and other biological resources and puts at risk the health of residents of coastal states who rely upon fishery products in their diet. Destructive fishing practices causing heavy loss of corals; land reclamation affecting coastal areas; and erosion of shoreline areas, are significant issues throughout much of the region. Accidental spills of oil and chemicals and operational discharges from vessels are important concerns now, and will become even more significant issues as vessel traffic increases to support economic growth.

To address issues like those mentioned above, considerable attention is being given to identifying marine pollution prevention and management programs. Many programs to prevent and manage pollution in the East Asian Seas hold considerable promise. These include proposals to improve navigation and reduce the chance of oil spills, to improve spill-response capability in the event spills occur, and to reduce operational discharges and disposal of wastes from vessels. Other actions would improve the management of marine pollution from a variety of land- and sea-based sources.

Many of these actions are costly, however, and resources are limited, particularly for developing countries. Choices must be made concerning whether, where and to what extent programs should be implemented. These choices require trade-offs to be made, which means relative benefits and costs must be considered-implicitly, if not explicitly. Yet, the lack of information about the benefits and costs of management actions often hinders the development of sound management programs. For example, no studies have assessed the benefits and costs of designating regional seas as marine special areas, nor has a careful study been done to date of the benefits and costs of establishing electronic charts and integrated navigational systems (marine electronic highways). No assessment appears to have been done of the human health benefits of actions to reduce pollution of regional seas by nutrients, pesticides and metals. These are major issues, but weighing the benefits and costs of programs to address these (and other) concerns has not been done.

This document provides a benefit-cost framework for managing land- and sea-based pollution in the East Asian Seas. Benefit-cost (and cost-effectiveness) analyses increasingly are being used to contribute to resource management decisions. In the past, benefits and costs were viewed narrowly; those occurring outside the market place tended to be overlooked. Ignoring the non-market environmental effects, however, implicitly and inappropriately assigns them a value of zero.

It is increasingly being recognized that assessments of resource management programs must take a broad view of benefits and costs. Benefits and costs are now generally understood to include both the value of resource services traded in the market place (e.g., vessel transportation, aquaculture products, landings from open-access fisheries, or fish or wood from mangroves), and the value of services that are just as real but are not directly exchanged in markets (e.g., ecosystem productivity effects, shoreline protection, human health, biodiversity, scenic amenities, recreation).

Several important limitations are noted. First, this document does not give a detailed review of available concepts and valuation methods. The particular method(s) to be used in specific cases depend upon: (1) the nature of the issue, (2) the availability of data and (3) the funding and time available. A vast literature sets out the formal concepts, available methods and data requirements; and the applicability, strengths and limitations of these methods are generally understood (e.g., Braden and Kolstadt, 1991; Freeman, 1993; Kopp and Smith, 1993; Grigalunas and Congar, 1995). The framework, guidelines and examples given in this document outline appropriate general concepts to account for benefits and costs, indicate steps to be taken, and how some of the concepts and methods have been or should be applied. However, it is not feasible to attempt to guide the reader through all the methods that might be used and all of the issues that can arise in particular cases.

Second, it is recognized that not all benefits and costs can be quantified in monetary terms; some actions necessarily will be based, in whole or in part, upon qualitative considerations best handled through an administrative/political process. In some such instances, sufficient quantification of benefits or costs may be possible to contribute to a decision; in other situations, cost-effectiveness may be appropriate, and benefits may not be explicitly assessed at all. And, in still other situations, the case for or against a particular program may be so obvious that a formal study may not be needed.

In any case, a benefit-cost (and cost-effectiveness) framework provides a useful perspective. It encourages those involved to think about: (1) what are the benefits and costs of particular programs? (2) what alternative programs exist to address a pollution management problem? and (3) what are the costs and results of each alternative?

Third, and finally, it is useful to recognize that decisions concerning pollution prevention and control measures rarely are based upon the outcome of a single technical analysis from any field. Even when very good data are available, benefit-cost analyses or other technical studies do not substitute for good decision-making, which necessarily involves a variety of political, cultural, scientific and other factors, in addition to benefits and costs.

Introduction

Purpose and Scope

This document provides a framework and guidelines for benefit-cost analyses of marine pollution prevention and management in the East Asian Seas. The framework adopts concepts and methods from the fields of environmental and natural resource economics and applied benefit-cost analysis, focusing on problems central to marine and coastal resources. Special emphasis is given to resource valuation and its potential role in improving benefit-cost analysis to address management of East Asian Seas pollution issues.

The benefit-cost framework and guidelines presented in this document complement ongoing work in environmental risk assessment being done for the East Asian Seas. Risk assessment provides a science-based methodology for ranking pollution concerns by the degree of risk posed to ecosystems and human health, using standardized measures of risk (Calow and Forbes, 1997). However, actually *managing* risks through use of economic or regulatory policy instruments has important societal consequences. Hence, risk management necessarily requires consideration—either implicitly or explicitly—of the benefits and costs (or the cost-effectiveness) of the management actions.

The basic argument underlying this report is that objectively done, benefit-cost analysis provides concepts and an organizing framework for pulling together disparate information that can be used, in many cases to contribute to management decisions concerning land- and sea-based pollution affecting regional sea areas. Furthermore, the combination of benefit-cost analysis and cost-effectiveness analysis, and environmental risk analysis as presented in Calow and Forbes (1997), provides a potentially very valuable, integrated approach for risk management. The combination of the two sets of concepts and methods can help:

1. prioritize marine pollution risks, and

2 analyze trade-offs between environmental risks and the associated benefits and costs of proposed programs to manage those risks.

Equity—fairness—is a major factor in many policy decisions. Hence, objective information about who gains, who pays and how much can be a very important part of analyzing the socioeconomic effects of proposed actions. Benefit-cost analysis, as such, does not provide measures of gains and losses to different individuals, stakeholder groups or areas. However, information gathered during benefit-cost analyses often can readily be used to provide an understanding of how benefits and costs are (or might be) distributed among stakeholders, as illustrated in examples given later in this document.

Organization of this Report

The remainder of this document is organized as follows. First, fundamental concepts from environmental and natural resource economics are introduced. These emphasize (1) the role of the marine-related natural resources of the East Asian Seas as natural assets, (2) the services these natural assets provide directly and indirectly to people and (3) the economic value of these services. Second, market failure and its sources and consequences are described. This is followed by a discussion of the need for, and nature of, benefit-cost and cost-effectiveness analysis for pollution risk management.

Third, the major methods for valuing benefits and costs using market and non-market approaches are summarized, examples and data needs are given and key strengths and potential issues and problems are indicated for each method. Finally, four examples of benefit-cost analysis are given:

1. Marine electronic highway - Malacca Straits;
2. Benefits from avoiding adverse health effects from contaminated seafood - general;
3. Avoiding losses to tourism and fisheries from sedimentation of coral reefs due to logging - Philippines; and
4. Environmental degradation and sustainable coastal tourism - Sri Lanka

The examples were selected to cover a wide range of important and common issues facing the East Asian Seas. In each case, background information is provided and key issues are sketched. Then, actual and (when necessary) hypothetical numbers are used (1) to illustrate and make concrete the framework and concepts developed in the text, and (2) to suggest *some* major issues faced and data needed in order to do a proper analysis. Throughout the discussion of the framework and case studies, examples are given and suggestions are made that can serve as guidelines for particular applications.

It is emphasized that the examples given should *not* be viewed as a careful benefit-cost analysis. Rather, the examples were selected to illustrate the potential application of benefit-cost concepts and methods to a range of important and common marine pollution management issues in the East Asian Seas.

Concepts and Methods

Coastal and Marine Natural Resources as Natural Assets

The natural resources of the East Asian Seas can usefully be thought of as *natural assets* that contribute to the well-being of residents and visitors. A distinguishing feature of assets—natural or otherwise—is that they can provide a sustainable stream of valuable services (dividends) to people over time, if properly used and maintained. Indeed, the value of the sea's natural assets can be expanded, perhaps greatly, through improved risk management of sea lanes (e.g., a marine electronic highway), mangroves; corals; other actions to control marine pollution; and through improved management of open-access resources, e.g., fisheries.

Natural assets, as noted, provide *services* to people. The services provided can be *direct* or *indirect*:

1. Direct services include, for example, use of sea lanes, harvests of fish, exploitation of mangroves for wood, viewing of corals and fish, and beach use.

2. Indirect services occur, for example, when fish that spend their juvenile stages in a mangrove are harvested off-site, perhaps many kilometers away.

Services have a value to people, where *economic* value is the most someone would pay for an item rather than go without it. Hence, economic value is fundamentally human-based. Several types of economic value can be associated with the services provided by natural resources. These include:

1. *Use value,* which is the *most* someone would pay to enjoy a resource service either directly or indirectly.

    a. *Direct* use value arises from physical or on-site use of a resource, for example, commercial or recreational fishing, visits to a beach or marine park and reduced exposure to pollution.

    b. *Indirect* use value occurs when one enjoys, for example, (1) the off-site services of mangroves or corals, such as biodiversity or shoreline protection or (2) pictures of resources in magazines or on television.

2. *Non-use (or passive use) value* refers to the economic value someone might have for a natural resource, over and above any use value. For example, some may value preservation of a resource or site of national significance (e.g., eagles in the Philippines), even if they do not actually see or use it themselves. Even relatively common resources may have a passive use value.

3. *Total value* is the sum of use value *plus* non-use value.

Table 1 summarizes information concerning key natural resources, examples of on-site and off-site services they provide, and the nature of the benefit from these services (i.e., market or non-market values). Also indicated in Table 1 is who benefits, broadly speaking, from the resource services.

Critical Issues Posed by Market Failure in the East Asian Seas

Problems inherent in the nature of shared waterways and coastal resources make sustainable use of their natural assets an elusive goal. These inherent problems include widespread failure of markets to work properly due to (1) negative externalities, (2) public goods and (3) lack of clear property rights (Grigalunas et al., 1997).

1. *Negative Externalties* arise when one party imposes costs on others without having to pay for the costs imposed. Important examples in the East Asian Seas are discharges of contaminants by agriculture, industry, households, loggers and vessel operators. Conversion of ecosystems, such as mangroves and peat marshes, to other uses that lead to pollution or saltwater intrusion are additional important illustrations. Destructive fishing practices, such as using explosives or poison to capture reef fish, are common and dramatic examples of negative externalities.

   Externalities are a major issue. When costs forced upon others are not taken into account, polluters do not face the true costs of their actions. As a result, they have no incentive to reduce the negative externality by, for example, decreasing the level of the activity, changing production practices, or moving to another site. In these cases, too much of the environmentally unfriendly good is provided, and those suffering the consequences of polluting activities in effect subsidize consumers of the good.

   To illustrate, conversion of mangroves to shrimp aquaculture at some sites causes saltwater intrusion that contaminates nearby rice paddies. The aquaculture developer has a net gain, but nearby rice farmers experience reduced productivity. The developer and the consumers of shrimp do not bear the true costs of aquaculture operations, including the costs imposed on rice farmers.

Table 1. Natural Assests of East Asian Seas: Services, Nature of Benefits and Who Benefits.

Natural Asset	Selected Services Provided	Nature of Benefits	Who Benefits
Sea Lanes	Transportation	Cost savings from moving oil, chemical and cargo	Littoral States, Regional Extra Regional
Fisheries	Seafood, viewing	Value of harvest,viewing and associated tourism	
Mangroves	<u>On-site:</u> Biological wood, charcoal fish Biodiversity <u>Off-site:</u> Fish Storm protection Erosion control Reduced sedimentation *(protects seagrass & corals)* Biodiversity	 Subsistence/market value Ditto Non-market /existence value Subsistence/market value Value of damages avoided Value of property saved Fish/subsistence/market value/tourism Non-market/passive value	 Littoral States Littoral States Littoral States ? Littoral States Littoral States Littoral States Littoral States/ international Littoral States/others
Seagrass Beds	<u>On-site:</u> Fish habitats Other marine life Protects corals fish tourism <u>Off-site:</u> Storm protection Erosion control	 Subsistence/market value Ditto Non-market (divers) Subsistence/market value Market & non-market value Value of damages avoided Value of property saved	 Littoral States Littoral States Littoral States Littoral States/ international Littoral States Littoral States
Peat Marshes	Same as mangroves	Same as mangroves	Same as mangroves
Corals	<u>On-site:</u> Fish <u>Off-site:</u> Erosion control	 Commercial/subsistence Aesthetic, tourism Value of property Tourism (hotels, diving operation)	 Littoral States Littoral States/international Littoral States Littoral States/international

2. *Public goods* have the unique attribute that, if provided for one, they are available to all. Instances of important public goods in the East Asian Seas include vessel safety measures, such as navigational aids; actions to promote water and sediment quality; cleanup of solid waste; flood and storm damage control measures; and the off-site services (e.g., shoreline protection) provided by corals and mangroves.

No one can be excluded from benefiting from a public good, and as a consequence, most individuals will not willingly pay for the good. This raises the classic free rider problem whereby beneficiaries of a public good will not pay, and it is the rationale for the existence of many government programs and for their financing through compulsory means, i.e., taxes and fees. Hence, if public goods are to be provided, the government (or another collective group) must assume a leadership role and use taxes, fees or community penalties or rewards.

3. *Lack of clear property rights*, unless offset by effective community management of resources, leads to the familiar 'Tragedy of the Commons' (Hardin, 1968). Natural resources are exploited beyond optimal levels, and capital, labor and other inputs are not used efficiently.

Significant examples of this in East Asian Seas areas include (1) overexploitation of open-access fisheries, (2) failure of farmers to invest in practices that prevent erosion due to the uncertainty that they can recapture the investment and (3) public overuse of mangroves.

The vast wealth provided by the many resource services of the East Asian Seas areas cannot be sustained unless the sources of market failure outlined above are addressed.

Linkages Between Benefit-Cost Analysis, Risk Assessment and Risk Management for Marine Pollution Prevention and Management in the East Asian Seas

Figure 1 reflects the interface between risk *assessment* and risk *management*. Risk assessment is a science-based inquiry in which pollutants are prioritized on the basis of their relative risks to the environment or human health.

Risk management, in contrast, takes into account the costs and benefits (or cost-effectiveness) of dealing with priority pollution problems identified in a risk assessment. Hence, risk management complements risk assessment by providing information for decision-makers about what society gives up (opportunity costs) and gains (benefits) from undertaking pollution management actions.

An initial risk assessment for the Malacca Straits has identified pollution priorities (Calow

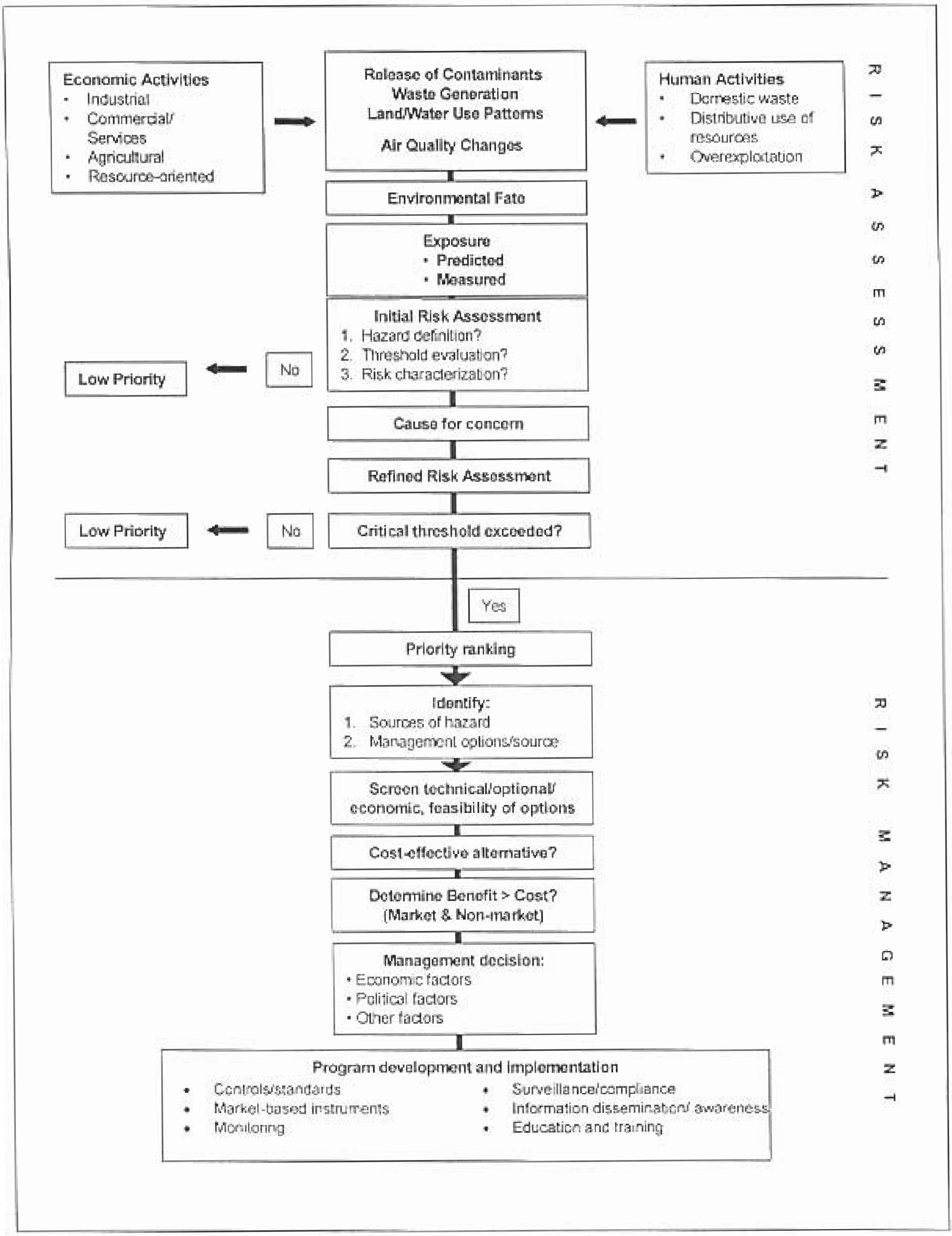

Figure 1. Risk Assessment/Risk Management Framework.

and Forbes, 1997). Many ongoing and planned management actions have as their goal to reduce the threats posed by land- and sea-based marine pollution in this area. Prioritizing these actions and implementing them for the Malacca Straits and other areas, however, requires development of (1) criteria to identify preferred actions and (2) policy instruments to implement them successfully.

This document makes the case that benefit-cost analysis (or cost-effectiveness analysis) is a potentially valuable tool for addressing marine pollution management issues. The case is also made that benefit-cost (or cost-effectiveness analysis) used in combination with formal risk assessment can enhance effective policy in two important ways. First, it focuses attention and scarce resources on key pollution management issues, i.e., those with the greatest risk. Second, it examines in a transparent way trade-offs—benefits and costs—that necessarily arise and must be faced, implicitly if not explicitly.

Benefit-Cost Framework for Subregional Sea Areas

Below, a general benefit-cost framework is set out to contribute to the selection of pollution management actions. Then, a cost-effectiveness framework is described, recognizing that in many cases it might not be feasible or possible to include money measures of benefits. As noted, later sections (1) summarize methods for estimating benefits and costs and (2) provide simplified examples to illustrate the framework and highlight data needs and methodological issues.

Benefit-cost analysis involves the estimation of a net present value where benefits and costs are very broadly defined:

$$\text{Net Present Value} = (B_d - C_d) + (B_e - C_e) - M$$

where:

B_d = benefits from the development or program

C_d = costs of the development or program

B_e = environmental benefits from the development or program

C_e = environmental costs from the development or program

M = mitigation costs

All benefits and costs are the *incremental* effects (i.e., effects with versus without) the development or program and are measured in *constant dollars*.

Benefits, B_d, are the value of the additional goods or services provided by a development or program. Benefits may be measurable through markets, either as:

1. the value of *additional output*, e.g., the value of timber from logging, oil from offshore fields, fish from aquaculture, or the value of land created through coastal reclamation[1]; or

2. the benefits could be *cost savings*, e.g., from improved navigation due to channel dredging or a marine electronic highway.

B_d also often involves services, e.g., recreation, human health or shoreline protection, that are not directly measurable in markets and require use of non-market valuation techniques.

C_d includes the costs incurred for labor, capital and other inputs to realize B_d. C_d can be divided into *investment* costs (planning, land acquisition, facilities construction, equipment, etc.) and *annual operating and maintenance* costs. Market cost usually provides an adequate measure of the opportunity costs of resource inputs. However, adjustments may be required, for example, when otherwise unemployed resources are used (see discussion below and the example given in next section).

B_e, benefits to the environment, could reflect lower environmental costs due to the development or program. For example, fewer oil spills might occur due to a marine electronic highway since the same amount of oil could be moved with fewer tanker trips[2]. A sewage treatment plant might reduce human illnesses and also improve the odor or appearance of waters.

Costs to the environment, C_e, captures environmental costs that result from the development or program. Examples include: the lost value of services provided by healthy coral when a nearby logging project increases sedimentation; losses to rice farmers due to saltwater intrusion and reduced shoreline protection when mangroves are converted to aquaculture uses; and coastal ecosystem productivity losses from coastal land reclamation.

Finally, M, is the *mitigation* cost—the cost of avoiding the adverse effects of a development or activity. For example, port developers may be allowed to expand operations using nearby natural habitats, only if they restore or prevent loss of other nearby lands providing similar ecosystem functions; aquaculture developers may be required to restore the land to its original state; loggers may be compelled to adopt best practice environmental measures, or conversion of a mangrove might be allowed only if the developer restores or acquires for preservation a comparable mangrove area elsewhere.

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[1] *Note that the market value of land is derived from the land value of anticipated future annual revenues less costs, i.e., it is the net present value of the productivity of the land created.*

[2] *As described in this paper, a marine electronic highway (MEH) could allow vessels to carry a greater load since underkeel clearance may reduce with MEH as opposed to the current system.*

Note that only *direct* benefits and costs have been included. Three important problems commonly arise when considering the scope of benefits and costs to be estimated and included in a benefit-cost analysis: (1) secondary or multiplier effects, (2) transfers and (3) double counting. These are to be excluded in benefit-cost analyses, for the reasons given below.

1. *Secondary, indirect or "multiplier" effects* include impacts in related, support industries. These are omitted from the benefit-cost framework presented in this report. Those who advocate adding secondary effects to direct benefits often multiply an initial change in output or income from an activity by 2, 3 or even 4 to get a 'total impact'. When multipliers are used naively, virtually any activity—conceivably an activity with *no benefits* at all—is inappropriately cast in what appears to be a very favorable light (Grigalunas and Congar, 1995).

   The problem with using secondary or multiplier effects is the implicit assumption that resource inputs such as labor, land or capital used in supporting coastal activities have literally *no* alternative uses—zero opportunity costs. Yet, when land, labor or capital are used in one activity they are diverted from other activities, i.e., they have an opportunity cost, and this must be recognized. Failure to recognize opportunity costs treats resources as if they were free and greatly exaggerates impacts. If multipliers of 2, 3 or even 4 that appear in some claims were accurate, then any project would appear to be a desirable investment and a good use of society's scarce resources.

   To be sure, in some areas unemployed labor may be a major issue, particularly in developing countries. In such cases, it is appropriate to take into account the use of otherwise unemployed resources. The correct way to do this, however, is not through the use of multipliers; rather, the correct approach is to adjust the market cost of the input to better reflect its true opportunity costs (its shadow value).

   A practical approach for estimating the shadow value of labor when calculating costs is to adjust downward the wage rate using the unemployment rate in the area. For example, if workers are paid $2 per hour, and the unemployment rate is 20%, then labor costs for a coastal activity or project, part of C_d[3], could be calculated at $1.60 per hour (=$2 (1-Unemployment Rate)). The effect of making this adjustment to reflect use of unemployed resources is to lower C_d and by that, raise B_d - C_d[4]. The last case study (see next section) illustrates the calculation of a shadow value for use of unemployed labor when assessing the benefits and costs of a coastal program.

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[3] *Attention is focused on unemployed labor, a major input in most projects, but similar arguments apply to all resource inputs.*

[4] *Note that in principle the use of any otherwise unemployed resource may justify an adjustment to estimate its appropriate opportunity cost (shadow value).*

2. *Transfers* also are excluded from a proper benefit-cost analysis. This is because transfers are mere redistribution of money among members of the community and do not represent a real change in benefits or costs. For example, additional taxes paid by business due to improvements resulting from a pollution management program are increases in government revenue (and by that, gains to those who benefit from government programs financed with that revenue). However, the additional taxes are a cost to those in the community who pay them. Hence, taxes within the same community are not a net increase in well being to the community as a whole, they are transfers among members of that community[5].

3. *Double counting* arises when a benefit or cost is counted twice. For example, increased benefits to recreational beach users due to a pollution management program that improves water and beach quality is a benefit (B_d) and should be counted as such. The same program might increase shoreline property values, and this could be used as a measure of B_d. But it would not be appropriate to include *both* measures since they are just different ways of measuring the same benefit, and to use both estimates would be double counting[6].

It should be understood that all benefits and all costs in the above equation are discounted, that is, the annual flow of benefits and costs over time are converted to a Present Value (PV), using a social rate of discount, r:

$$PV_B = B_1/(1+r)^1 + B_2/(1+r)^2 + ... + B_T/(1+r)^T = ?_t\ B_t/(1+r)^t$$

$$PV_C = C_1/(1+r)^1 + C_2/(1+r)^2 + ... + C_T/(1+r)^T = ?_t\ C_t/(1+r)^t$$

where B_t and C_t are the benefits and costs at time t.

The correct social rate of discount is a matter of debate that is far beyond the scope of this paper (see, e.g., Hanley and Splash, 1993). Generally speaking, however, the use of a long-term, real (adjusted for inflation) government bond rate is a practical alternative. This rate normally will be lower than the rate of interest on long-term bonds in the private sector, which reflect an element of risk[7].

The key criteria in benefit-cost analysis is net present value, which is the difference

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[5] *Taxes paid by "outsiders" are a gain to the community and should be taken into account, if important*

[6] *Property values increase because the improved nearby water quality enhances recreation for residents*

[7] *In some cases, the government agency involved may require that a certain rate be used or that the rate on a particular security (e.g., a specific long-term bond) be employed. Thus, in these cases, r is administratively determined and is not a decision to be made by the analyst.*

The golden rule is that activities with a positive NPV, that is, whose discounted benefits (what society gains) are greater than their discounted costs (what society gives up) are worthwhile, while those with a negative NPV are not.

Note that it is possible that:

$(B_d - C_d) > 0$ but $(B_d - C_d) + (B_e - C_e) < 0.$

That is, the 'private' benefit to a resource developer or user may be positive, but the overall effect on society is negative when environmental benefits and costs are taken into account. This is a common case, in fact, and illustrates classic market failure in the form of externalities. Of course, in many cases development benefits may exceed environmental costs, including mitigation.

Finally, the NPV provides a way to select the best scale of a development or program. Ideally of course one would like to pick the optimal scale. In Figure 2, the optimal scale of a program to reduce contaminants is indicated as that point where (discounted) total benefits less total costs are maximized.

Considerable uncertainty often surrounds estimates of some benefits, or perhaps some cannot be quantified in monetary terms at all. Given this uncertainty, one might view the range indicated as 'acceptable' as a practical target area. A more conservative, i.e., precautionary, view might control contaminants beyond the 'optimum' indicated in the figure, given important uncertainties. As indicated, a comparison of benefits with costs might suggest that very low and very high levels of contaminant removal might be too little or too much.

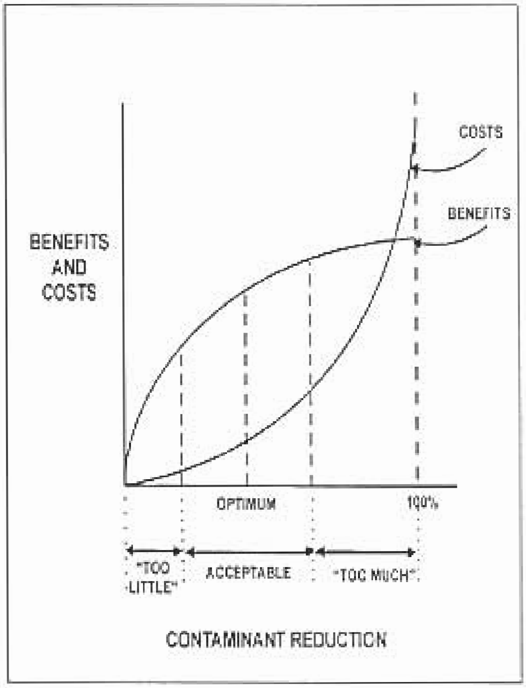

Figure 2. Benefit-Cost Analysis.

Another issue concerns the optimal scale of a project. As a practical matter, it may be that an activity can be carried out at discrete levels, e.g., small, medium and large. For each scale of activity, the NPV would be calculated, and the scale of operations with the highest NPV would be the best scale for the activity in terms of a benefit-cost framework. Again, a precautionary approach might be adopted, using benefits and costs as suggestive rather than hard numbers.

Finally, it is important to recognize further the difficult issue of uncertainty. Sensitivity analyses can be a very useful way of identifying how the results change when different, reasonable values for the variables of interest are considered, such as individual benefits and costs or the discount rate. Attention should focus on those variables that are both uncertain and important. Using this approach, the results indicate how the net present value varies as different values for the variables of interest are used. An extension of this involves Monte Carlo techniques. Here each variable of interest is characterized by a probability distribution (e.g., a normal or uniform distribution) with a mean and a measure of variation specified by the researcher, based on expert judgment. Using this method, one can estimate the expected value and the standard deviation of the net present value of the investment. Thus, one will know, for example, how the investment will perform on average and the percent of the cases for which the net present value will be negative.

In sum, viewing natural resources as natural assets provides a useful perspective on resource management. It encourages consideration of all benefits and all costs of risk management decisions, over time; and it also encourages thinking about the sustainable use of resources. Assuming the goal of a society is to obtain the largest net economic benefits (broadly defined) from the use of coastal and marine resources over time, developments or programs that maintain or raise the value of natural assets are preferred to those that do not.

It is easy to describe benefits and costs from risk in general terms, but quantifying benefits and costs can be difficult. The next section provides an overview of valuation methods, data needs and the strengths and weaknesses of different resource valuation methods. The examples given in the next section, adopted or adapted from the literature, are used to illustrate the nature of benefits and costs, the data needs and other challenges involved with estimating their value.

Market and Non-market Methods for Valuing Resource Services

Market methods are used for those services where benefits and costs are traded in organized markets. For example, marine transportation, offshore oil, port activity, commercial fishing and tourism are all activities that take place on organized markets. Normally market data (prices, quantities and costs) are available to estimate the benefits and costs of these activities, although information may be difficult to obtain in some cases.

Non-market methods are needed to estimate the economic value of resource services not traded on organized markets. Non-market methods include (1) revealed preference approaches, (2) stated preference methods and (3) mixed methods. Non-market methods also encompass (4) the productivity approach, (5) avoidance costs or averting behavior and (6) benefit-transfer.

1. *Revealed preference methods* assume that individuals disclose their preferences for resource services (e.g., beach use, proximity to a park or a clean environment) through their actions—for example, incurring travel and other costs to visit a beach, or paying more to rent or buy property nearer a park or with a cleaner environment—just as consumers reveal what they like through market purchases. Revealed preference methods use information from related markets to estimate the value of non-market service. Two major revealed preference methods are the travel cost method and the property value (hedonic) method.

a. The *travel cost* method estimates the value of a *site* (e.g., a beach, park, wildlife area). To do this, researchers survey a sample of site visitors to examine the relationship between recreationists' incremental costs (including the value of their time) and the number of visits to the site. There is an inverse relationship between visits to a site and incremental costs; this information can be used to estimate the economic benefits (consumer surplus[8]) of site use.

Principal problems with this approach include (1) determining the value of time, (2) dealing with trips with multi-purposes, (3) specifying the nature of the relationship—e.g., linear, semi-log—between number of trips and costs (and other variables, e.g. age and income) and (4) accounting for substitute sites[9].

b. The *property value* method recognizes that the value of property depends on its attributes or characteristics. Data are obtained on the market price of a property and on each important attribute. These include: site attributes (land area, size of home, sewage, running water, etc.), neighborhood attributes (e.g., distance from work, shopping, schools, congestion) and environmental attributes (distance to a park or a beach; water quality, odor, noise, other environmental attributes). Given these data, statistical methods are used to explain how each attribute affects the value of property.

Major problems include availability of data and correlation among some attributes (e.g., land area and size of home). Another problem includes specification of the correct relationship (linear, log-log, etc.) between property value and all of its attributes.

2. *Stated preference* methods are based on respondents' statement of their willingness to pay (WTP) to use, protect or restore natural resources and their services. In contrast with market methods and revealed preference approaches, it is valuation using words, not actions.

a. *Contingent valuation* relies on creation of a 'constructed market' for a resource or environmental service(s) in a carefully developed survey. The survey asks a sample of respondents their WTP for a specific resource service(s).

Important advantages of CV are: It is highly flexible and is the only method that

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[8] *Consumer surplus is the difference between the most someone would pay and what they actually pay*

[9] *The Random Utility Model, an extension of the TC model is the state-of-the-art for estimating the value of an activity. It uses individual data versus zonal information, and is well suited to including substitute sites for the activity. A discussion of this method is beyond the scope of this paper; see Freeman (1993) for additional information.*

can directly estimate passive use value. Potential problems with CV include its hypothetical nature and the questionable ability of respondents to distinguish a particular good from a broader set of all such goods. Other possible problems include symbolic behavior, "good cause" effects, and importance and compliance effects[10].

b. *Contingent choice* asks respondents to a survey to compare and rank programs to protect or restore specific area resources (e.g., mangroves, corals, forest lands, open space, etc.). The results (1) indicate the priorities respondents have among resources and (2) may provide an estimate of the total value (use plus non-use) for each resource.

Contingent choice is very flexible and may avoid many of the potential problems with CV. For example, people may find it easier to make tradeoffs among resources than to respond to a WTP question. Also, compliance effects may be avoided since the "socially correct" response may not be evident. However, excessive complexity must be avoided, and hypothetical, and symbolic effects may be a problem.

c. In a *contingent behavior* study, respondents are asked (1) if they would continue to use the site if the price or the characteristics of the site were changed in specific ways and, if so, (b) *how often* would they use it. This information allows the researcher to estimate what recreational demand for the site would be with the proposed changes as compared to the current (without) demand. The difference in consumer benefits between the with versus without cases is a measure of the benefit of the change in price or characteristic of the site.

In addition to the above methods, two additional non-market methods are commonly used to value services not traded directly on markets, the productivity approach and averting/avoidance behavior. These are outlined below.

3. The *productivity approach* looks at the relation between inputs (e.g., area of mangroves or corals and effect of pollution exposure) and outputs (e.g., wood, fish, shellfish, human health). The outputs are then valued using market prices (e.g., price for fish, shellfish and wood sold; wages for human labor). Establishing relations between inputs and outputs can be done statistically or using simulation, but fundamentally rely upon underlying biological/ toxicological relations and can be difficult to estimate, particularly for off-site services (e.g., fish caught elsewhere; human health impacts).

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[10] *Symbolic responses arise when respondents do not distinguish between the specific service being studied and more general environment concerns. Importance effects occur when respondents attach exaggerated significance to an issue by virtue of the fact that the researcher went to so much trouble. Good cause effects arise when respondents get satisfaction out of "doing good" rather than (or in addition to) valuing the specific good being studied. Compliance effects arise when respondents give answers that they think the interviewer wants to hear.*

4. *Averting or avoidance behavior* attempts to measure non-market value by using data on market purchases made to avoid an environmental problem. For example, the cost of revetments made to protect a shoreline exposed to erosion due to mangrove removal might be used as a proxy to value the protective function of the mangrove. Or the purchase of an air conditioner or water filter may reflect the value individuals attach to clean air or water, respectively.

   Averting or avoidance behavior methods have the potential problem that economic value may be understated since individuals may have been willing to pay *more* than they did, e.g., for the air conditioner or water filter. However, avoidance costs will overstate benefits, if a better alternative exists at a lower cost, e.g., if shorelines can be protected at a cost lower by a method other than revetments. Finally, there will be no clear link between a purchase and the value of a specific environmental service, if the market purchase provides multiple valued services, e.g., air conditioners cool homes *and* filter air; water filters remove pollutants *and* may improve taste. In these cases, it may be impossible to uncover the true motivation for the purchase.

5. Finally, *benefit-transfer* can be used as a simplified, quick and low-cost approach. This non-market method makes use of existing studies done using any of the methods mentioned above:

   Benefit-transfer (B-T) involves adopting or adapting an economic value (e.g., value of a beach day) estimated for one area and using it in another area. Obvious advantages of this approach are that it can be done quickly and cheaply. This alternative is especially attractive for (1) small projects where a major, costly study using original data may not be warranted and (2) preliminary, "desk-top" assessments to consider whether to launch a major policy study.

   A potential very serious problem is that the value might be inappropriate to transfer. Another issue is that at the present time, relatively few studies are available for some areas and transferring results from developed countries (where most studies have been done) to developing countries is problematic.

   Criteria for applying B-T are that (1) the original study be of adequate quality; (2) the activities and sites must be 'comparable' and (3) the quality change at the two sites must be similar. To enhance the use of B-T, the estimated value can be adjusted to reflect, for example, differences in household income between the original study site and the location where the program may be implemented.

Table 2 summarizes the major methods outlined above that are available to value resource services, gives examples of the types of services to which they can be applied, and indicates basic data needs. Also indicated are some key potential strengths and weaknesses of each method.

Table 2. Summary of Resource Valuation Methods, Examples, Data Needs, Strengths, Issues and Potential Problems.

Methods	Estimates	Examples	Data Needed	Strengths	Selected Issues and Potential Problems
Market Models	Producers effects Consumers effects	Transportation, oil, aquaculture, fish, tourism	Change in net revenue Change in price	Relies on actual market data	Data availability, model, specification
Property Value (Hedonic)	Implicit value of environmental attribute	Scenic amenities, noise, odor, pollution	Property values and amenities by site	Based on real transactions	Data availability, correlation among attributes, model specification
Travel Cost (TC)	Value of site	Recreation at site	Participation, incremental costs, socio-demographic data	Based on actual transactions-participation	Value of time, multipurpose trips, model specification
Productivity Approach	Value of resource services and human capital	Ecosystems (mangrove, corals, wetlands), human health, other pollution impacts	Output-input relationships or dose-response functions	Allows for estimate of value of natural functions and human health	Need biological/ science estimates; data availability, especially for off-site services
Contingent Valuation (CV)	Value of activity, site, environment and resource quality and/or quantity change	Amenities, water quality, biodiversity, recreation, human health	Survey responses on willingness to pay for resource services	Flexible; only way to estimate directly passive use value	Hypothetical, part-whole; symbolic responses, compliance & importance effects
Contingent Choice	Priorities among and perhaps value of natural resources	Open space, parks, mangroves, corals, forest lands	Survey responses to resource/cost choices	Flexible, avoids some problems with CV	Choices must not be too complex; hypothetical, symbolic, importance effects
Contingent Behavior	Value of hypothetical, quality or price change	Recreation activity, others	Same as TC Survey plus responses to proposed change	Extends TC for proposed quality of price changes; flexible	Same as TC; hypothetical
Avoidance Costs Averting Behavior	Value of clean water, air, solid waste reduction, shoreline protection	Clean air, water; waste reduction, erosion /damage control	Cost of (least cost) averting measures (e.g., air and water filter, shore revetments)	Allows estimate of non-market commodities on absence of first-best data	May underestimate value; joint products may prevent estimate of service of interest
Benefit -Transfer	Value of activity, site, environmental and resource quality and/or quantity change	Recreation, water and air quality, others	Adopt (or adapt) available economic value estimate made for other sites	Fast and low cost, flexible	Activity, sites and quality change must be comparable between sites. Original study must be of adequate quality. Few studies available in developing countries.

In some cases, it may not be possible to quantify certain benefits due to time, budgetary or other reasons. Or, society may have adopted a specific environmental goal, which is to be taken as a given. In these cases, the question becomes: What is the best—least-cost—way to achieve the given goal? Examples of issues that might be addressed with cost-effectiveness analysis include: Which is the best mode for shipping a given amount of oil between two points, pipeline or tankers? Which is the lowest-cost alternative, among several options, for controlling runoff of animal wastes from agriculture? What is the least-cost way of meeting an environmental goal, e.g., for controlling urban runoff, for a coastal area? Which approach offers the least expensive way to meet a public health goal?

In such situations, cost-effectiveness analysis and information on incremental costs can contribute to land- and sea-based pollution risk management decisions. Two situations are described below. One involves finding the least-cost alternative for achieving a *given* pollution control goal; and the second concerns decisions about how much pollution to control.

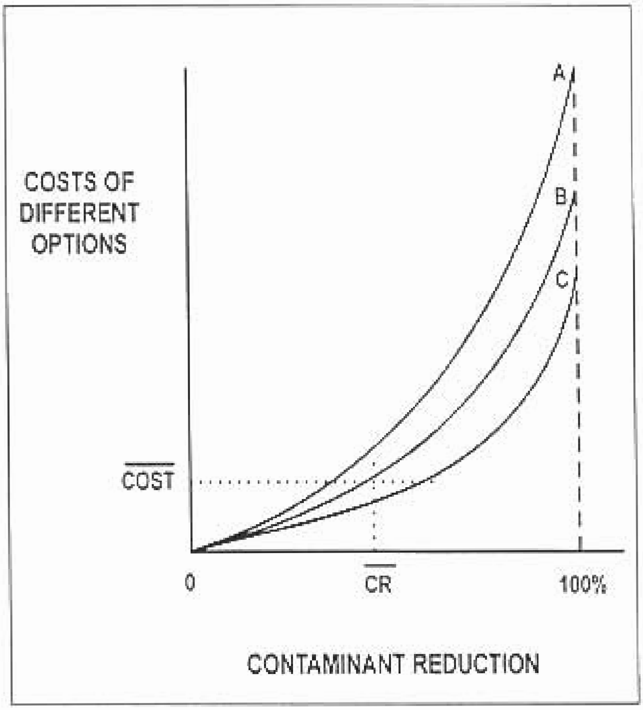

Figure 2. Cost-Effectiveness Analysis.

Figure 3 shows the simplest case where an environmental problem can be addressed in three ways A, B, and C. In this simplest of all worlds, option C is clearly the cost-effective approach. It allows a given objective, CR, to be achieved at lowest cost; or looked at another way, it allows for the greatest pollution reduction for a given outlay, COST.

In most situations, however, selection of an option will not be so obvious. For example, suppose two, mutually exclusive alternatives, A and B, are available for reducing pollution by a given amount. Alternative A has high initial investment costs (I_{Ao}) at time zero but low annual operating costs (C_{At}), while B has lower initial investment costs (I_{Bo}) but higher yearly operating costs (C_{Bt})[11]. If both lead to similar results in terms of protecting or restoring marine resources, which is the preferred action?

[11] *Note that in the text we now distinguish between the initial investment cost, I, and other costs to illustrate the point being made, whereas earlier for convenience, all costs were included in "C".*

Because the two alternatives differ with respect to their initial and annual costs, the choice between them are not obvious. A cost-effectiveness standard would select the option which has the *lower* present value (PV) of costs as in the following comparison:

$$PV_A = I_{A0} + ?_t C_{At}/(1+r)^t \quad \text{Versus} \quad PV_B = I_{B0} + ?_t C_{Bt}/(1+r)^t$$

Note that the alternative selected depends upon (1) the costs *and* their time profile, (2) the discount rate r and (3) the scale of the pollution control undertaken. Thus the selection of the best—least-cost—alternative may not be obvious without careful study of the alternatives. Suppose instead several mutually exclusive ways to reduce pollution in varying degrees exist, each with a different cost, and the decision concerns *how much* to remove. Again, it is assumed that the benefits of these actions cannot be considered for some reason. This kind of issue is common and arises, for example, when decisions are being made concerning cleaning up contaminated marine sediments (National Research Council, 1979; Grigalunas and Opaluch, 1989), controlling runoff, deciding upon the level of sewage treatment, or deciding upon the combination of methods to reduce air pollution.

Without minimizing the difficulties involved, useful insights may be obtained in each case by examining the least-cost ways of addressing these issues and the incremental costs of more stringent levels of control. Generally, limited, initial reductions can be achieved at relatively low cost. However, costs begin to increase after the easy cleanup measures are adopted and, at some point, the incremental costs of further pollution control increase sharply, as in Figure 2. Indeed in Figure 2, too much cleanup leads to a situation where costs actually exceed benefits.

Given this information on incremental costs, policy-makers are in the position to ask: "Are the additional benefits likely to justify the extra costs for the additional pollution control?" Hence, cost information alone, judiciously used, can provide useful insights and contribute to risk management, even when information on benefits is not available or cannot be used[12].

Summary

Boxes 1 and 2, respectively, summarize steps in the cost-benefit and cost-effectiveness approaches. The framework set out in this section can be applied to most risk management problems. In the following section, three very simplified examples are given to illustrate some of the concepts outlined above.

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[12] *Tradeable pollution permits, an incentive-based approach, is another alternative. For further discussion see Grigalunas and Congar (1995).*

Examples of Benefit-Cost Analysis

Introduction

This section provides examples of benefit-cost analysis for pollution risk management to illustrate the framework set out in the previous chapters. It is emphasized again that the examples presented below are highly simplified and do not reflect all of the important facts for the cases considered. Rather, the examples are given simply to illustrate some of the concepts and methods described in preceding sections.

Marine Electronic Highway - Malacca Straits

Background

Vessel safety is an important concern in the Malacca Straits, due to the busy vessel traffic, difficulties in navigating the Straits, aging vessels and the abundance of sensitive ecosystems and resources. Concern with safety will become an even more significant issue as vessel traffic increases to support economic growth in the region and in other parts of the world. To enhance safety and improve the loading capacity of tankers, a marine electronic highway (MEH) is being developed for the Straits. This illustration looks at the potential benefits of an MEH in terms of lower transportation costs and environmental benefits from potentially fewer oil spills.

Large oil spills can impose several major costs (see, e.g., Grigalunas et al., 1988, 1997; MPP-EAS, 1999). Response and cleanup costs can be considerable, as can the costs of assessment. Financial losses to aquaculture and mariculture operators, tourism resorts and other businesses also can be large.

Depending upon the location and size of a spill, extensive control and cleanup activity could cause sections of the Straits to be temporarily closed, imposing potentially major costs on shippers and perhaps on their customers. Public perceptions also can play an important role, as in the case of the *Exxon Valdez*, where fisherfolks asserted a claim for some $900 million for alleged reduced prices for their product caused by unfavorable publicity.

Oil spills pose particular threats to the services provided by productive and sensitive ecosystems, such as mangroves, peat marshes and seagrass beds, and to fisheries and other resources and uses of the Straits (Calow and Forbes, 1997). Under international conventions and some domestic laws, restoration of natural resources injured by a spill is required, and restoring natural resources can be expensive (Mazzotta et al., 1995; Grigalunas et al., 1997). Furthermore, natural resources injured in a spill may not be as productive as unaffected resources, so that there is an interim loss of on- site and off-site value (for which polluters are liable in some countries) until the resources recover.

A (Very) Simple Partial Benefit-Cost Analysis

In this case, the benefits—B_d, using the notation given above— are cost savings resulting from the fact that fewer tanker trips will be required to transport the same amount of oil through the Straits[13]. Environmental benefits, B_e, should also result since there likely will be fewer accidents with a smaller number of tanker trips. As will become apparent, however, the issues are not so clear cut and considerable research will be required to estimate credibly benefits and costs.

Some major simplifying assumptions and hypothetical numbers are used to illustrate the issues that must be addressed, and the information needed, to do a careful benefit-cost analysis. Use of an MEH will allow tankers to carry more oil per trip. Assuming that the amount shipped annually through the Straits is a given, one can begin by estimating the reduction in the number of tanker trips due to the ability to carry more oil per trip. For simplicity, assume there is only *one size vessel* that carries V_b barrels per trip before the MEH and V_a after, and of course, $V_a > V_b$. Assume further that the tanker cost per trip is C.

If the amount sent through the Straits annually is a constant Q_t, then the yearly number of trips (T) required in time t before (b) and after (a) the MEH is:

Before: $Tb_t = Q_t / V_b$

After: $Ta_t = Q_t / V_a$

and the cost savings from fewer trips, or B_d, is:

$$B_d = (T_{bt} - T_{at})\ C = (Q_t/V_b - Q_t/V_a)C$$

Assuming a spill rate of R, a major spill size of S, and a constant environmental cost per barrel spilled of EC, the environmental cost savings, i.e., the benefits B_e, from fewer spills due to MEH would be:

$$B_d = (Tb_t - Ta_t)\ ([(R)(S)\ (EC)])$$

[13] Alternately the cost savings might be viewed as the lower costs per barrel moved due to tankers carrying more barrels of oil per trip.

Simply by way of illustration, assume hypothetically that MEH reduces annual (loaded or eastbound) tanker trips by 700 per year (roughly 2% of the some 35,000 tankers passing through the Straits), that a trip is 4 days, and that the vessel cost per day is $50,000.

With these assumptions the annual cost savings for petroleum tankers due to fewer trips is:

B_c = 700 x 50,000 X 4 = $140 million

Using a *major* spill rate of 1 per 34,000 tanker trips through the Straits, a major spill size of 10,000 barrels[14], and environmental costs per barrel of US$5,000 (one-fourth that of a very rough estimate for the *Exxon Valdez*)[15], the yearly environmental benefit from MEH from the reduced number of tanker trips would be:

700 x 1/34,000 x 10,000 x $5,000 = $1 million

Three points must be noted. First, the calculation of environmental benefits is only for the estimated 700 *fewer* tanker trips per *year* due to the MEH—not for all of the 35,000 plus trips through the Straits that occur each year. Second, the $1 million in reduced environmental costs from the 700 fewer tanker trips is an annual *expected value*. Under the assumptions used, if a 10,000-barrel spill actually occurred, and its associated cost in fact was $5,000 per barrel, the environmental costs for the incident would be $50 million. Third, the figures do not include benefits from the possible reduction (1) in the major spill rate due to, for example, fewer groundings post-MEH or (2) in *small spills* or operational discharges due to fewer tanker trips. Hence, environmental benefits, B_e, may be understated in this regard.

Thus, using the many strong simplifying assumptions and the hypothetical numbers described above for illustrative purposes, the *annual* benefit is $141 million. Discounted over a 25-year period at a rate of 5%, the present value of the annual financial plus environmental *benefits* from the MEH is about $2 billion. (Note that possible reduction in the cost of radar and other navigational aids that littoral States currently use but may not be needed due to the introduction of the MEH have not been included in the calculations in the text.)

To estimate the NPV of the Malacca Straits for transportation due to the introduction of the MEH, it is necessary to subtract out all MEH-related *costs*, i.e., C_d, and any cost to the environment, C_e. C_d includes the costs of planning, installing, operating and maintaining the MEH. These costs are not known and, as a result, are described only by broad category in this paper. If the present value of the costs of the MEH is less than $2 billion, then the NPV will be positive, and the MEH is a good investment overall. Note that the NPV is the *change in the asset value* of the Straits for transportation, as a result of the MEH.

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[14] *This uses information from Calow and Forbes (1997) who, using data for the Malacca Straits, estimate a large spill risk of .000029 and define large spills to be > 5,000 barrels (1 barrel = 42 gallons).*

[15] *This assumes a social cost of $4 billion for the approximately 250,000 barrel 1989* Exxon Valdez *spill in Alaska.*

Some Considerations Concerning Distribution of Benefits and Costs Among Stakeholders

If markets are competitive, a reduction in vessel transportation costs eventually will lead to reduced costs for cargos shipped through the Straits. This means that eventually consumers in the importing States will receive much of the B_d—the cost savings—due to the MEH. Hence, to understand who gains, we must understand who are the consumers of goods, particularly petroleum, transported through the Straits.

Using the summary of trade information in Morisugi et al. (1992), East Asia is the primary destination for petroleum products from the Indian Ocean (which includes the Middle East). However, many regions receive petroleum and bulk cargo shipped through the Straits. Hence, a first impression is that (if vessels moving bulk cargo also experience reduced transport costs due to the MEH), the benefits from an MEH may be concentrated in East Asia but may well be distributed fairly widely among regions. Note again that if littoral States can avoid current navigational costs, such as radar, they will capture this cost savings.

Distribution of the costs of an MEH is not clear at this point. Ultimately, the distribution of costs will depend upon what sharing arrangement is made among the concerned countries. Several alternative arrangements are possible (e.g., no. of vessels, tonnage, tonnage of cargo, or the value or type of cargo); and each arrangement could lead to a different distribution of costs.

Discussion and Important Qualifications

Clearly, an MEH is a very complex undertaking. To measure properly the net benefits of the MEH, it is necessary to refine *greatly* the data and methods used. For example, the amount of oil shipped through the Straits over time will increase, and this must be estimated. This could be done most easily by using the growth in vessel traffic over time; it also could be done, indirectly, by predicting the increase in goods imported and exported by countries using the Straits (i.e., by estimating the derived demand for the Straits). Also, it is necessary to examine the size distribution of tankers in order to estimate the reduced number of vessel trips and the cost savings per trip avoided, since costs are a function of tanker size (and other factors).

The calculation in the text assumes a fixed spill rate and used an average spill size of 10,000 barrels. Apparently, the age of a tanker and other factors affecting the spill rate (Murad, 1995) merit consideration in a full study. The average major spill could be larger than 10,000 barrels and, as noted, minor spills were ignored. Data on past spills could be examined to estimate an expected spill size and variations in spill size (i.e., a frequency distribution—most likely an exponential distribution with many small spills and very few large spills).

Careful attention also must be given to the potential magnitude of environmental costs. One possibility, for example, would be to use a unit oil spill cost but scale it to reflect the sensitivity of resources in different areas of the Straits. The location of past spills, given in Murad (1995), might be a guide to the expected location of future spills in the Straits, and the mapping of resources being done by the GEF/UNDP/IMO Regional Programme could be used to scale the expected cost of a spill in different sections of the Straits.

Other potentially important factors should be noted. Apparently, very large tankers now use the deeper and wider Lombok Strait rather than the Malacca Straits; this more roundabout route to East Asia requires an additional three days steaming time (Morisugi et al., 1992). An MEH might allow larger tankers to use the Malacca Straits, by that actually *increasing* the number of large vessels transiting the Straits. This could increase environmental risks.

Another consideration is the potential for an induced demand for use of the Straits. This would happen if the cost per ton or product delivered decreases due to the MEH, and the cost savings are passed along to consumers, which is the likely case under competition. In this case, the demand for products will increase at least slightly, by that increasing traffic in the Malacca Straits[16].

Finally, annual data must be gathered for all MEH cost categories: investment (planning, designing and equipment) and operating and maintaining the MEH. Data also are needed for current navigational safety costs, for example, radar that might not be needed when the MEH is put in operation.

Benefits from Avoiding Adverse Health Effects from Contaminated Seafood

Introduction

Seafood safety is a major concern worldwide, particularly in countries where fish plays an important role in diets. Policy options for dealing with seafood safety include closing contaminated fishing areas believed to present a threat and controlling the sources of the pollution. Improved testing for safety, public warnings against consuming contaminated seafood and public education are other policy options, but are not considered here. Consumer responses include substitution of non-contaminated for contaminated species, and different food preparation/consumption practices (e.g., avoid eating certain raw seafoods).

Carrying out a benefit-cost analysis is issue- or source-specific. This example assumes that the source(s) of contamination has been identified, as well as the least-cost approach(es) for controlling the pollution, so that all investment and operating costs of treatment to control the source, i.e., C_d, are assumed to be known. Hence, attention is focused on benefits, B_d, but especially on B_e.

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[16] *Estimating these effects requires consideration of demand elasticities and related economic information.*

Health problems from eating tainted seafood include physical discomfort, time off work due to illness and medical treatment in severe cases. In very severe cases, mortality can occur. The benefits from improving seafood safety, B_d, include:

1. Reduced medical costs

2. Less time off work

3. The value of feeling better

4. Value to others (e.g., family and friends) of reduced illness.

Other benefits from reducing pollution include the value of additional fish harvests, less the costs of these harvests, assuming fishing grounds closed due to pollution can re-open when pollution sources are controlled. This benefit can be important, but is not considered further in order to focus on benefits relating to health effects.

To estimate B_e it is first necessary to estimate the anticipated reduction in illnesses due to the environmental improvement. Perhaps an expert medical assessment of this issue has been made and can be used. Otherwise, estimates of reductions in illnesses might be made by undertaking a statistical analysis of the relation between consumption of contaminated fish species (primarily shellfish) and associated illness. To do this, one would need cross-section (or time series—or both) data on the per capita consumption of contaminated fish species[17] and on the incidence of illnesses (gastro-intestinal and perhaps other illnesses) caused by eating contaminated seafood, by sub-area. Because of lack of data on fish consumption, fish landings of the contaminated species might be used as a proxy for fish consumption for each area. Data on illnesses should be available from local hospitals, although this would understate actual cases since many illnesses may not require hospital visits. For a preliminary analysis, it may be possible to adapt estimates from other areas (see, e.g., Caulkins et al., 1988). If one can obtain reliable estimates of the relation between seafood consumption per person and incidence of illness, this information can be used to infer benefits.

Other explanatory variables also may need to be considered, e.g., per capita income or the price of substitute foods. For example, if the seafood species posing the most risk was an inferior good (i.e., consumption decreases as income goes up), then a given location with a relatively high income may have little illness because they consume little of the species. Some investigation of fish consumption patterns clearly is in order.

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[17] *Calow and Forbes (1997) give health risk parameters from consumption of fish that perhaps could be used in such an analysis. Also, see US Environmental Protection Agency (1985).*

Information on medical costs for treating illness should be readily available from local hospitals. Time off work can be valued using a fraction of the wage rate as an estimate of lost output to society. Suppose, for example, that a person earns $10 per day, that illness due to eating contaminated seafood causes them to miss on average 2 days of work, and they incur $25 in medical costs. Then the value of the lost output is $20 per illness, and total cost per illness would be $45. The $45 is the measure of the costs of pollution; looked at another way, it is the benefit from reducing pollution.

The value of feeling better is more difficult to assess, but people plainly are willing to—and actually do—pay to feel better, e.g, for aspirins and other medications to relieve discomfort. Estimates of these avoidance costs might be useable, or perhaps survey results on this subject done in other areas could be adapted for use.

The value individuals attach to another family member or friend feeling well is no doubt real (as evidenced by the time relatives devote to care for ill family members), but there do not appear to be any reliable estimates of this value.

Distribution of benefits and costs in this case appears to be relatively straightforward. The public would benefit from improved health. Fishers would benefit if previously closed areas become available for fishing. The public would pay higher costs for controlling the pollution source, either through user fees or, perhaps, general taxes. Again the investment and operating and maintenance costs would need to be assembled; these would vary by source (e.g., sewage treatment as compared to control of agricultural pesticides or industrial metals).

Discussion and Important Qualifications

As noted, critical data are needed. Information on consumption of contaminated seafood and incidence of illness is needed for each sub-area for enough sub-areas to have the variation and degrees of freedom necessary to obtain useful statistical estimates.

Ecological Costs to Coral Reefs and Fisheries from Sedimentation Due to Logging - Philippines

Introduction

Hodgson and Dixon (1992) evaluated alternative development plans for Bacuit Bay in the southwest Philippines where two industries, tourism and fisheries, are in competition with a third, the timber industry. This is an important case study because the conflicts in Bacuit Bay are common in many sections of Asia. Hence, a similar framework could be applied elsewhere. Bacuit Bay is a relatively remote, very attractive area. Services provided by the Bay include fisheries and a high level of water quality and marine-related scenic amenities that support artisanal and commercial fisheries as well as tourism operations focusing on the Bay. The high quality of the water, extensive coral reef formations and an abundance of reef fish make this a very attractive destination for scuba diving.

Construction of roads and skid trails to support timber operations along the Bay's drainage basin have created serious sedimentation problems and reduced coral cover and the diversity and abundance of reef fish species. Sedimentation from logging is exacerbated by the topography of the area which is characterized by steep slopes which pose an erosion hazard. Coral grows slowly, and loss of living coral cover would likely take many years to replace. Hence, logging could impose significant, long-term external costs on fishing and tourism.

A Simple Partial Benefit-Cost Analysis

In terms of the benefit-cost framework developed in this paper, the benefits from logging B_d, were relatively easy to establish. The present value of logging revenues over a 10-year period, using a discount rate of 10%, was $9.8 million. No cost information was available, so C_d is unknown.

Environmental costs, C_e, were more difficult to establish but were estimated using the loss in productivity approach. Regression analysis was used to estimate the dependency of fish abundance and diversity on living coral reef. Briefly stated, this analysis established: (1) that every additional 400 tons/km^2 of annual sediment deposition in the Bay decreased coral cover by 1%; (2) that one coral species was lost (extinction) in the Bay per 100 ton/km^2 annual sediment deposition and (3) that for each 1% annual decrease in coral cover, fish biomass decreased by 2.43%. Loss of tourism due to the reduced amenity services of corals and reduced fishing revenues as a result of sedimentation was based on judgmental estimates.

The above estimated productivity relationships were used to examine two policy options: (1) continuation of logging versus (2) banning of logging. For each of these two options, total revenues for fishing, tourism and logging were estimated over a ten-year period, using a variety of assumptions concerning the growth in tourism and fishing and sediment loading from logging. Hodgson and Dixon (1992) found that the present value of total revenues (using a 10% discount rate) for the three activities combined was much larger (by $17.6 million) with the policy banning logging as compared with the policy of continuing logging ($43 vs. $25 million in 1986 US dollars).

To summarize, the NPV of the reduction in revenues B_d due to banning logging was more than offset by the environmental benefits, B_e, to tourism and fishing. Unfortunately, information could not be obtained on the costs of the various activities so the net effects are unclear. Presumably, the conclusion reached when costs are included would be the same

In this case, gainers would be fishers, tourism operators and employees, and recreationists and tourists. Losers would be logging operators and their employees.

Introduction

Hikkaduwa, located on the southwest coast of Sri Lanka, has been an important tourist destination and an important source of income for local businesses and residents. However, degradation of the environment threatens the sustainability of tourism activity at the site. Important issues include solid and domestic waste, destructive use of coral reefs (including coral mining and damage from tourism boats) and overfishing of reef fish.

Barker (1995) studied the private and the social benefits and costs of a special area management (SAM) plan for this area. Her analysis of private (financial) benefits and costs assessed the returns to tourism businesses due to improved treatment of solid and domestic wastes. She estimated the extra investment and annual operating costs for waste collection and treatment. She also estimated the benefits by comparing projected growth in tourism profits with improved waste collection and treatment as compared to the no-collection and treatment case. On the basis of a comparison of costs with benefits, she concluded that the provision of improved waste management facilities was a good investment from a financial point of view.

To estimate *social* benefits and costs, other broader factors involving non-market benefits and costs had to be considered, and certain adjustments of the private benefits and costs were required, as is described below. For example, she used the results of two contingent valuation studies to estimate the economic value recreationists put on beach use and use of the reef. Briefly, users of the reef (divers) were asked their willingness to pay to a fund to ensure preservation of the reef; beach users were asked their willingness to pay to access the beach. Also included were the net benefits of a new Visitor's Center, measured by estimated extra revenues minus the costs. The costs of prohibiting mining of coral also was considered (although the resulting benefits, e.g., beach erosion prevention were not).

As noted, several adjustments of private costs were made to estimate social benefits and costs. For example, items such as taxes paid by tourism operations (mostly locally-owned) are not costs to society as a whole; they are transfers from one group (tourism businesses) to another (society through government) within the same society. Hence, taxes had to be added back to private benefits to estimate social benefits. Also, the unemployment rate in the area was high (13%); to take account of the use of labor that would otherwise have been unemployed, money labor costs were adjusted downward by 13% to reflect better the true opportunity cost of labor. Costs of incremental social welfare operations were included, using staffing costs for these activities; possible increases in crime, prostitution and incidence of AIDS were described qualitatively.

Overall, the SAM had a positive net present value (NPV) for every scenario considered in a series of sensitivity analysis, except for one worst case scenario. The fact that the cumulative NPV was estimated to be positive after only several years (a short payback period) provides reassurance to those concerned about uncertainty of the investment over an extended period.

Distribution of Benefits and Costs

An analysis of the gains and costs of the SAM concluded that most (72%) of the gains would accrue locally to the tourism industry. International visitors also gained 22% of all benefits) in that their economic benefit from the use of the beach and reef (measured by their willingness to pay) was less than their cost (the cost in fact is near zero for those already at the site). National economic welfare also would increase by capturing part of the gain in locally-generated tax revenues.

The SAM plan cost would account for most (72%) of the costs, and this would be distributed across various groups. A big loser would be coral miners (27% of all costs). A search for alternative employment for this group was recommemded.

Discussion

This study is an interesting application of benefit-cost analysis from several viewpoints. First, a benefit-cost analysis was done from a private as well as a social perspective, illustrating how financial and broader valuation (market and non-market) estimates can be judiciously assembled and integrated to address important, challenging and common coastal issues. Second, the analysis of the distribution of benefits and costs was important: by demonstrating the substantial benefits that would be received by the tourism industry, this important stakeholder group became proponents of the SAM.

Summary and Conclusions

The benefit-cost framework and guidelines and the outline of valuation methods developed in this report set out concepts and methods that can be used to contribute to environmental risk management in the East Asian Seas. These concepts and methods were illustrated, in a very simplified way, using four examples dealing with widely differing, yet common, pollution management issues.

It should be obvious that actually implementing this framework will not be a mechanical exercise; rather, it will require considerable effort, judgment and careful analyses. This is not surprising. Pollution risk management issues facing the East Asian Seas are important and complex; many conceptual issues must be resolved in particular applications, and data must be artfully assembled.

Methods and data that could be employed to carry out benefit-cost analyses for risk management were presented. The expected results will depend upon the issue being studied. For the four example projects, expected results would include:

1. quantitative measures of impacts, for example,

   a. (i) the reduced annual number of vessel trips to deliver oil through the Straits; and

      (ii) reduced oil spillage, for the MEH;

   b. (i) reduced pollution discharges; and

      (ii) fewer illnesses due to controlling sources of seafood contamination;

   c. (i) reduced sedimentation; and

      (ii) reduced coral degradation from improved forestry practices;

   d. (i) reduced solid and domestic wastes; and

      (ii) additional tourism activity in the Hikkaduwa case.

2. monetary estimates of:

   a. the benefits and costs and net present value; and

   b. the distribution of the benefits and costs among stakeholders for each case.

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