Blue Pricing of Undersea Treasures

Needs and Opportunities for Environmental Economics Research on Coral Reef Management in South East Asia

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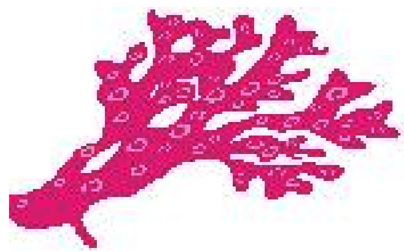

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Abstract

From 1994 to 1998, EEPSEA approved some 65 research projects in environmental economic analysis. Of these, 38 related to "brown" environmental issues, 23 to "green" issues, and four to other issues. None pertained to coral reefs. This relative dearth of coral reef analysis is mirrored in the broader literature; only seven separate environmental economic studies have been undertaken that address policy concerns in SE Asia or nearby areas on Papua New Guinea's and Australia's Great Barrier Reef. This paper calls on researchers to pay greater attention to the "blue" dimension of our global environment, commencing with the coral reef ecosystems.

Coral reefs in SE Asia represent about 30% of the world's reefs. They are currently undergoing unprecedented levels of degradation from stresses such as sedimentation, pollution, blast and cyanide fishing, and coral bleaching. Institutional weakness is pervasive and the proliferation of "paper parks" – marine protected areas with no effective protection – is alarming. Economic valuation of the coral reef asset, and of the damages wrought by institutional failures and various direct stresses, is thus of substantial policy interest. The paper provides a simple "benefit transfer" calculation using conventional methods, calculating a value of US$1.4 trillion for SE Asia's coral reefs. The flaws inherent in such an analysis, however, are discussed in some detail; they underline a greater need for original site-specific empirical studies that reflect local system complexities and local policy needs.

The paper summarizes conditions in the EEPSEA maritime countries – Cambodia, China (including Taiwan), Indonesia, Malaysia, Papua New Guinea, Philippines, Sri Lanka, Thailand, and Vietnam – and outlines potential policy priorities in each of these. Environmental economic analysis can assist in addressing some of these priorities through: (i) increasing awareness of absolute and relative economic values; and, (ii) providing valuation estimates that can assist in coral reef management.

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Chapter 1
Introduction

> "AND WHY THAT CERULEAN COLOR? The blue comes partly from the sea, partly from the sky. While water in a glass is transparent, it absorbs slightly more red light than blue. If you have tens of meters of the stuff or more, the red light is absorbed out and what gets reflected back to space is mainly blue. In the same way, a short line of sight through air seems perfectly transparent. Nevertheless – something Leonardo da Vinci excelled at portraying – the more distant the object, the bluer it seems. Why? Because the air scatters blue light around much better than it does red. So the bluish cast of this dot comes from its thick but transparent atmosphere and its deep oceans of liquid water. And the white? The Earth on an average day is about half covered with white water clouds.
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> ..... Look again at that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every 'superstar,' every 'supreme leader,' every saint and sinner in the history of our species lived there – on a mote of dust suspended in a sunbeam."
>
> – Carl Sagan. Astronomer and writer. 1994.

In 1990, while speeding out of the solar system, the Voyager spacecraft snapped photographs of the planets. From a distance of 3.7 billion miles, the Earth appears as a "pale blue dot" on one such photograph. Carl Sagan uses this metaphor in the above excerpt to underscore the insignificance of our home world in relation to the great expanse of space. But how insignificant is this blueness?

Blue Valuation

Much has been made of the greening of economics as analysts and policy makers have paid greater attention to the environmental linkages between economies and the ecological systems on which such economies depend. The United Nations Statistical Office now prescribes different ways of measuring green GNP, international economic aid has slowly but surely become greener, and, with thanks to David Pearce and colleagues (1989), England was among the first countries to have a "Blueprint for a Green Economy."[1] More recently, economists and others have started distinguishing between green environmental issues (such as deforestation, rangeland degradation, water availability, and wildlife habitat loss) and brown environmental issues (such as air pollution, water quality, sewage disposal, and solid waste management). Even though such categorization ignores the interconnectedness of all of these issues and the problematic categorization of some topics such as global climate change, we largely embrace such distinctions. The colour coding appeals to our reductionist tendencies, it permits foresters and water quality engineers to attend different conferences in good conscience, and it enhances the orderliness of our filing cabinets and bookshelves.

But while we look for important green or brown research topics, we typically overlook the blue dimensions of economic analysis. By the blue dimension I refer loosely to the 70% of our planet covered by saltwater oceans and seas, and the resources therein. Environmental economics seems largely to have ignored this realm to date, being content to leave it in the hands of fishery economists.[2] This relative neglect might be explained by a number of factors. First, property rights and jurisdiction over maritime resources remain difficult issues at all management and regulatory levels – local users, national institutions, and international bodies; policy choices are often not obvious. Second, people generally are less informed about marine issues; we are, after all, air breathers and land dwellers. Finally, in my view, there exists an unfounded complacency about ocean management because there is, in fact, no obvious problem; the ocean seems to hold unlimited wealth. But such perceptions of capacity have previously been responsible for irreversible changes in seemingly limitless or robust systems; from the near extinction of the American bison to the compromising of our protective ozone blanket, humankind's legacy is one of soiling our nest.

The oceans are not without their limits. While much of humanity depends on fisheries for their protein requirements, wild fish production peaked about seven years ago and the increased incidence of fishery collapses has underlined the fact that the seas are not limitless. And our dependence on the seas for non-food products is not diminishing. For example, terrestrial ecosystems are becoming less reliable as a source of medicines and antibiotics and new products. Our greatest hope for new cures is likely to be the unexplored areas of the oceans, the continental

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[1] See: Conroy and Litvinoff (1988), Pearce *et al*. (1989), and United Nations (1990).

[2] For example, literature reviews and searches typically show few environmental economics studies related to marine systems. Two electroncically searchable benefit transfer sites show this. The first of these sites is maintained by Environment Canada and is entitled "EVRI: Environmental Valuation Reference Inventory." At the end of 1998 it contained about 850 references, primarily relating to the valuation of freshwater-related issues. A search in its data base revealed no studies directly applicable to coral reef or ocean valuation. A search on a second site – spearheaded by the New South Wales Government in Australia (entitled ENVALUE) – yielded 14 hits, although the majority of these dealt with beach recreational values in temperate countries and only two had direct relevance to coral reef management. A comprehensive literature survey by Cartier and Ruitenbeek (1999) revealed 19 studies of direct relevance to marine system valuation; some of these were multi-site or multi-function studies and they hence generated a total of 41 specific valuation findings that might (in principle) be useful for benefit transfer purposes. [Note: the searchable electronic sites are located at http://www.evri.ec.gc.ca/EVRI/ and at http://www.epa.nsw.gov.au/envalue/StudyCnt.asp. The full literature survey is available at: http://www.island.net/~hjr.]

margins, and coral reefs. In early 1999, more than 30 drugs derived from marine species were under preclinical investigations by private and public research organizations, and by the National Cancer Institute (Mestel 1999).

In brief, we have largely been taking our oceans and seas for granted. If we are indeed, as environmental economists, designing blueprints for sustainable economies, it is time that we put the "blue" back into the blueprint and pay greater attention to the oceans.

State of the World's Coral Reefs

In this paper, I shall focus on just one part of the ocean resource: the coral reefs. Human activity has already taken a substantial toll on this undersea treasure trove. A coral reef ecosystem consists of some form of substrate, usually old dead reef, and a surface of living, growing, and reproducing coral animals. Thousands of species of fish, shellfish, worms, and sponges live in and around the coral reef. Even deep ocean pelagic species frequent reef boundaries and rely on the coral reef environment within a complex food web. Among the greatest dependents on coral reefs, and among the most significant threats to their well-being, are humans.

Recent results from extensive surveys of the reef systems suggest that degradation is widespread. While reefs have natural resilience to storms, sea level changes, and natural fluctuations in predatory species, a number of the impacts that humanity is inflicting in these systems are without precedent. Sedimentation from deforestation, pollution from organic wastes and agrochemicals, and over-fishing by dynamiting and cyanide poisoning are all examples of current threats to reef health. In 1997 and 1998, massive coral bleaching events occurred in some parts of the world; while the precise causes of coral bleaching are not yet known, many speculate that it is linked to global climate change and an unusually strong El Niño event (Box 1).

Economic Impacts of Coral Reef Degradation

One might reasonably ask, "So what?" Ecosystems are damaged daily through human activities, and many rehabilitate naturally or with the help of some modest investments. Why, indeed, should we worry about this degradation? Apart from the myriad of philosophical reasons, as economists we can boil this all down to a question of self-interest: Does it make economic sense to permit such degradation to continue? Do the benefits of reef degradation exceed the costs that we, or our children, must bear as a consequence?

Box 1. The Coral Bleaching Event of 1997-1998

There has been unprecedented bleaching of hard and soft corals throughout the coral reefs of the world from mid-1997 to late-1998. Information is coming in daily via the internet and from GCRMN and Reef Check teams. Much of the bleaching coincided with a large El Niño event, followed by a strong La Niña, but bleaching in other areas appears uncorrelated. Four overlapping levels of bleaching are apparent:

- 'catastrophic', with massive mortality (often near 95% of shallow corals) in Bahrain, the Maldives, Sri Lanka, Singapore, and in large areas of Tanzania;
- 'severe' bleaching with around 50-70% mortality, and also coral recovery, in Kenya, Seychelles, Japan, Thailand, Vietnam, and Belize;
- 'moderate and patchy' bleaching on some reefs in large areas, with a mix of coral recovery and around 20-50% mortality, but no effects in other parts, such as in Oman, Madagascar, the inner Great Barrier Reef, parts of Indonesia and the Philippines, Taiwan, Palau, French Polynesia, the Galapagos, the Bahamas, Florida, the Cayman Islands, Bermuda, and Brazil;
- 'insignificant' or no bleaching in large areas of the world's reefs such as the Red Sea, the southern Indian Ocean, the Andaman Sea, most of Indonesia, large parts of the Great Barrier Reef, most of the central Pacific, and parts of the southern and eastern Caribbean.

Bleaching and mortality were most pronounced in shallow water (less than 15 m) and particularly affected staghorn and plate Acropora and other fast growing corals. Many of the massive, slow-growing species bleached, but many recovered within 1 or 2 months. The consensus is that this is the most severe bleaching event ever observed, although in this case there were also more people looking specifically for bleaching following internet advice of the location of above average sea-surface temperatures. More observations and monitoring are required to determine whether bleached corals will recover (or die), and whether damaged reefs have the potential to 'bounce back'. More importantly, there is a need for continued observations to determine whether this is a rare, severe event, or part of a pattern of increasing disturbance associated with global climate change.

Source: Clive Wilkinson, 10 Dec 1998, Global Coral Reef Monitoring Network, press release.

Such questions are of key policy significance, but remarkably little rigourous attention has been paid to answering such questions. Much anecdotal evidence suggests that at least some of the values of coral can be economically significant. The Great Barrier Reef in Australia harbours a billion dollar annual tourism industry, as do the coral reef systems in Florida. Even individual parts of a coral reef may have significant value. When the Cunard liner Royal Viking Sun hit a reef in the Gulf of Aqaba some years ago, Egyptian authorities sought US$23 million in damages for the loss of about 2000 square meters of coral reef (Sheppard 1996). The implied price of US$10,000 a square meter seemed remarkably high at the time – it would make reefs among the most valuable real estate in the world – but the case served to focus more attention on the "art" of economic valuation, rather than on the value itself. Similarly, Bob Costanza and colleagues (1997, 1998), in a *tour de force* benefit transfer analysis, suggested that the reefs of the world had an annual value of at least $375 billion. Again, apart from attracting some necessary attention to the importance of the reefs, such economic values provide little in the way of policy guidance.

Box 2. Local uses and functions of coral reefs. Any of these may be the subject of economic valuation or analysis in an effort to set priorities for policy-making. (Based on Ruitenbeek and Cartier 1999).

Functions	Sustainable Uses	Non-sustainable Uses
• Global biogeochemical cycles • Breeding, spawning, nursery, feeding and foraging habitats for marine organisms • Coastal protection (self-repairing breakwaters that provide coastal protection) • Source of sand for beaches and dunes that support complex ecosystems • Source of information for medical, agricultural or industrial uses • Natural recorders of past climate and environmental variation • Educational opportunities	• Offshore fisheries • Reef fisheries (fin-fish, invertebrates, marine reptiles, marine algae) • Marine tourism • Mariculture • Biotechnology and bioprospecting (source of bioactive substances for medical and pharmaceutical uses) • Aquarium trade • Coral sand mining (limited) • Small-scale souvenir manufacture	• Coral and sand extraction for lime production, building blocks, other construction materials • Destructive fisheries • Large scale collection of reef organisms • Large scale aquarium trade • Development on reefs for landfill expansion or other construction

To get a better economic policy handle on a valuation problem, environmental economists often start by identifying the various functions that might be ascribed to a given ecosystem. This permits, minimally, identifying some key linkages with a view to establishing priorities about what functions might be of greatest value. In the case of coral reefs, such an approach yields about 20 key functions and uses (Box 2). The small number of studies that have been conducted on coral reef ecosystems generally highlight only a few of these functions, most notably those related to tourism, erosion control, and fisheries. Only one effort, sponsored as a five year project through the World Bank Research Committee (Table 1), attempts to synthesize multiple benefits into a single valuation.

Purpose of this Paper

The basic purpose of this paper is to address the question of “What can EEPSEA researchers contribute to addressing the management problems of coral reef degradation in South East Asia?” Of the ten countries in which EEPSEA is involved, nine have coastal areas with coral reef ecosystems. These include: Cambodia, China (including Taiwan), Indonesia, Malaysia, Papua New Guinea, Philippines, Sri Lanka, Thailand, and Vietnam. In its five year review, however, not a single research project had addressed this resource, and very few of EEPSEA’s projects

Table 1. Summary of economic valuation results – Montego Bay coral reef, Jamaica

	Benefit	Price*	
	NPV (MM$)	MM$/%	MM$/ha
Tourism/Recreation [1]	315.00	7.33	17.18
Artisanal Fishery [1]	1.31	0.03	0.07
Coastal Protection [1]	65.00	1.51	3.54
Local Non-use [2]	6.00	0.24	0.56
Visitor Non-use [2]	13.60	0.54	1.28
Subtotal	400.91	9.65	22.63
Pharmaceutical Bioprospecting (Global) [3]	70.09	0.23	0.53
Total (Global)	471.00	9.88	23.16
Pharmaceutical Bioprospecting (Jamaica) [3]	7.01	0.02	0.05
Total (Jamaica)	407.92	9.67	22.68

* Marginal benefits shown at typical current reef conditions in terms of change in benefit (in millions of US$) per % or ha coral cover.

Sources: Based on [1] Gustavson (1998), [2] Spash *et al*. (1998), [3] Ruitenbeek and Cartier (1999). Full studies relating to these World Bank Research Committee projects are available at: http://www.island.net/~hjr.

have focused on the marine environment. Of the 63 projects with a sectoral focus approved from 1993 to 1998, 38 might be categorized as “Brown”, 23 as “Green”, and only two as “Blue”.[3]

In addressing EEPSEA’s role, however, the paper intends to fulfill a number of functions. Chapter 2 provides an introduction to some of the biophysical characteristics of coral degradation and the types of threats that coral reefs face; this is done within the context of SE Asia countries, and relies extensively on information made available by the World Conservation Monitoring Center and by the Hong Kong University of Science and Technology. The chapter also provides a policy context for coral reef management. Chapter 3 reviews the relatively small body of literature relating to coral reef economics studies in SE Asia, drawing out key lessons. Chapter 4 outlines the specific research implications for EEPSEA

A key conclusion of all of this work is that EEPSEA can play an important role by conducting more site specific studies in coral reef management, focusing on some key functions such as erosion control, tourism services, and local product harvesting. Such studies will address an urgent need to expand the number of empirical results that are available relating to coral reef “prices”, while also permitting immediate input into pressing policy problems.

[3] This represents my assessment of 65 projects in total, 2 of which are non-sectoral in that they apply to resettlement and global climate change. Of the remaining 63, the “brown” class of projects includes those related to fresh water quality management and pricing. The two “blue” projects involve an analysis of overfishing in the Philippines marine fisheries sector (by Israel and Banson) and an institutional analysis of coastal fisheries cooperatives in the Philippines (Sumalde), neither of which address coral reef management issues.

Chapter 2
Coral Reefs in SE Asia – A Biophysical and Policy Context

"WHAT DIFFERENCE DOES IT MAKE how much you have? What you do not have amounts to much more."
– Seneca. Roman writer, philosopher, statesman. ca. 65 AD.

Seneca's words ring true on a number of fronts, particularly when faced with official statistics and information. Reef maps are often outdated, showing only general reef coverage even though it may now be dead substrate. Government economic statistics typically show only the obvious economic production from marine areas, ignoring the hidden externalities of coral reef degradation. Government policies typically identify the institutions responsible for specific domestic or international management efforts, rather than the enforcement effectiveness or the results of such commitments. Consequently, the reef degradation, the policy gaps and failures, and the economic losses that result never receive the attention they merit. In this chapter I shall focus, within the SE Asian context, on some of the biophysical degradation and the policy gaps

Specifically, the chapter:

- outlines key reef stresses;
- outlines selected international management and monitoring initiatives to contain these stresses; and
- summarizes key coral reef management indicators for EEPSEA countries.

Stresses on Coral Reef Ecosystems

Coral reefs are subject to a wide range of natural and human stresses, ranging from storms and hurricanes, to dumping of pollution and sewage, to poisoning from cyanide fishing, to destruction from coral mining or blast fishing. These pressures have increased as demand for reef based products – ranging from curios to seafood – has increased with world population and economic growth. In many parts of the world, various reef stresses have resulted in extensive degradation that usually takes the form of loss of live coral, loss of important food products, and loss of tourism and recreation benefits. But coral reefs also have a remarkable long-term resilience to such stresses, and can and do recover from even the most devastating impacts. As an extreme example, the coral reef systems that were totally destroyed during nuclear testing at the Bikini Atoll have now essentially completely recovered. The issue in such cases is not so much whether the ecosystems will recover; the issue is that the time scale for recovery is often so long that it places economic hardships on populations dependent on the coral reefs. A one year loss of subsistence fishery, or a multi-year loss of a commercial fishery or tourism industry, can quickly undermine economic stability.

South East Asian coral reefs form part of the Indo-Pacific reef systems (Map C1). The reefs in SE Asia represent among the largest systems in the world; approximately 30% of the world's coral reefs are here and it is regarded as the global centre of biodiversity for hard coral and many other reef animals and plants (Wilkinson 1998). Despite the establishment of marine protected areas (Map C2), the monitored reefs in this region have shown a steady decline in quality over the past 15 years, succumbing to sedimentation, pollution, and destructive fishing from cyanide or blast fishing (Jameson *et al*. 1995; Maps C3 to C5).[4] While the commitment to marine protected areas is apparently substantial (Annex B), International Coral Reef Initiative (ICRI) estimates that less than 10% of these are in fact well managed.

The degradation is evident from key indicators of reef health in the region (ReefCheck 1998). The amount of live coral in the Indo-Pacific system has declined from about 80% in 1997 to 65% in 1998. Almost 80% of sites surveyed showed no live lobster, and one half of the sites showed no large grouper; both of these species were formerly abundant and the decline is evidence of overharvesting and of overfishing using cyanide. Some species common to the Indo-Pacific have been eradicated at many sites: edible sea cucumbers are now absent from 62% of the reefs; giant clams bound for sashimi and curio markets were absent from 53% of reefs; and humphead wrasse were absent from 90% of the reefs. In marine protected areas (MPA) with effective management, however, one does find cause for hope: the typical "effective MPA" harboured 400 giant clams.

An important conclusion of the monitoring programs in SE Asia has been that the degradation is not isolated to populated centres. Remote regions are as heavily damaged as populated areas.

[4] Annex C provides a complete selection of maps relating to EEPSEA countries, showing major areas of coral reef cover.

International Management Efforts

The need for better coral reef management is being spearheaded by a number of key international efforts. Chief among these are:

- International Coral Reef Initiative (ICRI). ICRI was catalysed by the United States in 1994 and now has the participation of Australia, France, Jamaica, Japan, the Philippines, Sweden, UK, and agencies including the United Nations Environment Programme (UNEP), the International Oceanographic Commission (IOC/UNESCO), the World Bank, the International Centre for Living Aquatic Resources Management (ICLARM), and the South Pacific Regional Environment Programme (SPREP). An ICRI Workshop was held in the Philippines in May 1995 to enable countries, donors, development and funding agencies to work with coral reef managers, private sector representatives, non-governmental organisations and scientists to develop a Framework for Action that serves as a basis for achieving sustainable management of coral reefs and related ecosystems. This framework, reproduced in full in Annex A, has become a guiding manifesto for groups and individuals involved in coral reef management; over 100 countries have been consulted in designing the framework and some 80 countries have endorsed it.
- Global Coral Reef Monitoring Network (GCRMN). This is the formal international effort to provide more data an information on the status of coral reef health. It is sponsored by IOC/UNESCO, UNEP, the World Bank, and the World Conservation Union (IUCN). A major output of this network is ReefBase, a global database housed at ICLARM.
- ReefCheck. Coordinated through the Hong Kong University of Science and Technology, this global monitoring effort was first undertaken in 1997 and complements the GCRMN using a network of volunteers following scientifically designed consistent protocols for monitoring coral reef health. Coverage in 1998 was adequate to provide aggregated regional results, although for some countries the number of sites was inadequate to provide a statistically significant sample to make country-specific conclusions. ReefCheck 1999 is already underway and it is anticipated that country-specific results will be available from this survey.
- Reefs at Risk. This project is a collaboration of the World Resources Institute (WRI), ICLARM, and the World Conservation Monitoring Centre (WCMC), intending to produce a map-based indicator of potential anthropogenic threats to the world's coral reefs. The map-based analysis produces an indicator of potential threats to coral reefs from four broad categories: (i) coastal development; (ii) marine-based pollution; (iii) overexploitation of marine resources; and, (iv) inland pollution and erosion. To capture the potential threats to coral reefs from sources in these categories, distance-based threat surfaces were developed from 12 representative stressors. These include cities, settlements, airports and military bases, population density, mines, tourist resorts, ports, oil tanks and wells, shipping routes, and areas where blast fishing or fishing using poisons is known to occur. Additionally, a watershed-based model was used to estimate potential erosion within the watershed to produce an estimate of areas potentially threatened by inland pollution and sedimentation. The 13 threat surfaces were integrated with data on coral reef location, resulting in a global classification of potential threats to coral reefs.

Summary of Policy Priorities in EEPSEA Countries

Although it is probably safe to say that all maritime countries within SE Asia could benefit from better coral reef management, the relative policy priorities will differ from one country to the next depending on a number of factors. Such factors include: relative importance of marine zones and coral within those zones; current capacity to implement necessary institutional arrangements; and, relative stresses on coral reef ecosystems. In general, the types of policy interventions that would normally be important might include:

- Institutional Strengthening Policies. These include general institutional strengthening and capacity building, both for local management efforts and for meeting and addressing international obligations under conventions and treaties. Often such institutions and policies are the first step towards achieving effective management and the presence or absence of such policies can serve as a rough indicator of commitment. Research efforts targeted to awareness-building can play an important role in achieving the political support needed for such institutional strengthening.
- Policies to control land-based pollution. These generally need to address better management of wastes that might have direct impacts on coral reef areas. Where sedimentation and pollution impacts are evident, policies associated with integrated coastal zone management (ICZM) can be effective in addressing this "land-marine interface." Research efforts can support the identification of appropriate technical mechanisms for mitigating pollution impacts; within an ICZM context such measures also typically require substantial institutional strengthening.
- Policies related to over-harvesting of products. These will generally be required where over-fishing or over-harvesting is an issue, either because of inadequate or unenforced regulation, or because of the use of unsustainable harvesting techniques. Prevalence of blast fishing, cyanide fishing, or high levels of effort can be important indicators of over-harvesting; disappearance of key food products is an important biological indicator. Research efforts can assist in identifying appropriate interventions to reduce such impacts; interventions may cover a broad range of economic or other policies (e.g., removing fuel subsidies, promoting common property management, or enforcing protected areas.)
- Policies related to resource use conflicts. Unresolved resource use conflicts will have among the greatest immediate social, economic and environmental impacts. Where they occur, they often attract the highest policy priority. In marine areas, the most typical conflicts relate to fishing and tourism. Research can assist in identifying appropriate mitigation mechanisms such as marine zonation or compensation.

Table 2 provides my assessment of key biophysical and institutional indicators that might be used within EEPSEA countries to assist in identifying potential policy priorities. This assessment relies on information available through WCMC, ReefCheck, Reefs at Risk, as well as personal judgments of local institutional capacities based on experience within the region. General descriptions of reef coverage and importance of marine fisheries and marine protected areas are based on data, maps and documents maintained by the World Conservation Monitoring Centre (see Annexes B and C). A number of patterns emerge from such an assessment.

- Cambodia. Although coral areas are limited, Cambodia is the weakest of the countries in the sample in terms of monitoring and current institutional capacity. Policy priorities in the near-term are likely to focus on basic institutional strengthening and awareness-building.
- China (including Taiwan). Reefs in this area of the Northwest Pacific have been most prone to natural impacts such as typhoons and crown-of-thorns starfish, but concerns relating to over-fishing and the potential impacts of reef degradation on a growing tourism industry are likely to remain at the policy forefront. The region does have reasonable institutional and technical capacity to deal with such problems, and has established MPAs meeting international standards.
- Indonesia. This vast archipelago contains the broadest range of reef types and problems. Historical commitment to MPAs has been among the greatest in the region, but the recent economic crisis jeopardizes enforcement efforts while placing local resources at risk to non-sustainable harvesting from impoverished local populations. Policy interventions are likely going to rely increasingly on finding acceptable site-specific community-based management regimes.
- Malaysia. Although the country has a high dependence on its marine fishery, it harbours the first MPA in the region (dating from 1904), and has probably the greatest potential density (in the region) of marine protected areas. Most of Malaysia's MPAs remain as "paper parks" and fail to meet international standards for protected areas. Institutional strengthening and awareness building is therefore a high priority, with most site-specific problems likely focusing on potential sedimentation impacts and resource use conflicts involving tourism development.
- Papua New Guinea. PNG lies on the northern portions of Australia's Great Barrier Reef and enjoys a world-wide reputation for excellent marine recreation. Compared to other countries in the region, land-based impacts of pollution and over-fishing impacts are relatively low. Policy priorities rest primarily in mitigating future impacts and maintaining the resource base intact; this will require strengthening of the MPA system and the institutions and international conventions that support such a system. In contrast to other countries in the region, these institutions are relatively weak in PNG at this stage.
- Philippines. Philippines stands out as somewhat of an anomaly within the region. Stresses on the reefs are among the greatest of any of the countries in the region, and there is substantial commitment on paper to protecting the reefs. But institutional capacity is exceedingly weak; only 13 of 145 potential MPAs in fact meet international standards, and the country has yet to ratify key international agreements relating to living resources.
- Sri Lanka. Sri Lanka is often held up internationally as a model for marine system management. ICZM efforts have focused on local institutions and capacity building. In

Box 3. Two Major National Projects in South East Asia Coral Reef Management

Indonesia: Coremap and Bali 2000

Coremap is a very large coral reef management project that has started in Indonesia under international funding. Coremap has adopted Reef Check as one of its training methods for community-based monitoring. The next International Coral Reef Symposium will be held in Bali, in October 2000. As part of this event, an Indonesia-wide Reef Check will be held prior to the symposium.

Philippines: US AID Coastal Resources Management Project (CRMP)

The Philippines has adopted a Coastal Environmental Program that aims to coordinate all activities on resource and environmental management of coastal ecosystems with the involvement of the communities and immediate stakeholders in the protection and management of coastal zones. It relies heavily on information, education and communication (IEC) cum community organizing during the early stages to achieve higher levels of participation. Within this context, the CRMP has a component to address coral reef management; CRMP is based in Cebu, but is carried out nationally. One of the goals of CRMP is to develop a national coral reef monitoring protocol.

spite of such efforts, reef stresses from increased tourism and, more recently, coral bleaching threaten the sustainability of the resource. Policy priorities have now shifted to issues such as sustainable financing of institutions.

- Thailand. Policy priorities in Thailand will likely focus on mitigating the impacts of land-based pollution. While currently not a widespread concern, resource-use conflicts with growing tourism may be of importance in specific sites as Thailand continues to develop new areas. Institutional capacity in this country is relatively strong, and most policy research and interventions are likely to require site specific work.
- Vietnam. While the country does not have a large threatened accessible coral reef "estate", there are some interesting policy angles that can be explored within the context of coral reef management. Notably, coastal erosion is a pressing policy concern in the country, and reefs play an important function in controlling such erosion. The high incidence of bleaching and resultant coral death in the Vietnam region poses an opportunity for bringing coral reefs to policy maker attention.

In summary, from a policy perspective, one might imagine two general types of initiatives: (i) broad-based country wide institutional initiatives; and, (ii) site-specific interventions. From a research perspective, I would certainly argue that most of the solid requirements remain at the site-specific level. National policies and institutions can play a supportive role (see Box 3), but issues and problems do differ considerably from site to site; moreover, policies directed to such site-specific problems are more readily monitored and will generally have greater immediate impacts.

Table 2. Summary of selected biophysical and policy indicators relating to coral reef management in EEPSEA countries.

		Fishery			Marine Protected Areas (MPAs)				Conventions*						Coral Reef Stresses**				
	General Description of Reefs	Exclusive Economic Zone ('000 km2)	Marine Fisheries ('000 mt)	Marine Fisheries (% of total fishery)	First MPA/First IUCN MPA	MPAs (total # potential identified)	MPAs (total # IUCN Class I-VI)	MPAs (total area [km2] IUCN Class I-VI)	UNCLOS	LRHS	HS	IWC	SPREP	CMS	Sedimentation	Pollution	Blast/Cyanide Fishing	Bleaching	Resource Use Conflicts
Cambodia	May occur around some coastal islands	56	36.4	33%		0	0	0	✔	✔	✔				?	?	?	?	?
China	Patchy coral growth on mainland. Principally around offshore islands and archipelagos in the Nan Hai; most important area is Xisha Qundao. South Hainan has fringing reefs.	964	7607	58%		39			✔	✔	✔	✔			M	M	H	M	M
- Taiwan	Present everywhere except sandy west coast. Main development is in the south and as fringing reefs around some offshore islands.	536			1982/1982	12	6	1353							M	L	H	M	H
Indonesia	14,000 islands have reefs, mostly in the east. Fringing, patch and barrier reefs are found; few atolls.	5409	2380	75%	1919/1919	230	101	96769	✔	✔	✔				H	M	M	L-M	H
Malaysia	Shallow reefs on east coast and offshore islands, fewer off west coast.	476	606	98%	1904/1957	124	11	1755	✔	✔	✔				H	L	L	M	M
Papua New Guinea	Estimated 170,000km2 of coralline shelf in <20m depth and 40,000km2 of reef and associated shallow water in 20-30m depth. Milne Bay Province has greatest concentrations.	1728	12	47%	1973/1973	17	4	158	✔				✔		L	L	L	M	M
Philippines	27000km2 of coral reefs & communities throughout the archipelago, with largest concentrations in the south west.	1891	1699	74%	1932/1932	145	13	587	✔					✔	H	M	H	M	H
Sri Lanka	Few pure coralline reefs but extensive areas of coral are found around the coast, mainly close to shore and in the east.	516	174	88%	1938/1938	15	14	1762	✔	✔	✔			✔	H	M	M	H	H
Thailand	Few off mainland coast. Most around offshore islands, especially along west coast in the Andaman Sea.	325	2795	91%	1966/1966	17	14	4758	✔	✔	✔				M	M	L	L-H	L
Vietnam	Around several offshore islands but sparse on the mainland.	722	610	70%	1982/1982	2	2	302	✔						L	L	L	H	L

* Conventions:
- UNCLOS — United Nations Convention on the Law of the Sea
- LRHS — Convention on Fishing and Conservation of the Living Resources of the High Seas
- HS — Convention on the High Seas
- IWC — International Convention for the Regulation of Whaling
- SPREP — Convention on the Protection of the Natural Resources and Environment of the South Pacific Region
- CMS — Convention on the Conservation of Migratory Species of Wild Animals

** Stress Levels (Relative)
- L — Low
- M — Moderate
- H — High

[Bleaching: Thailand - Low on Andaman Sea; Indonesia - primarily Low]

Chapter 3
Role of Environmental Economics: What Price the Reefs?

"IF YOU CAN ACTUALLY COUNT your money, then you are not really a rich man."

– J. Paul Getty. US oil millionaire, arts patron. 1957.

Indeed, why bother counting one's wealth when it seems without limits? The value of large ecosystems, such as coral reefs, may have been heretofore ignored because it seemed almost infinitely large. But, as with the coral reef degradation and with the policy gaps identified in the previous chapter, the time has come that we must also start paying attention to the economic losses. We are quite likely getting poorer every day.

What is Coral Reef Economics?

The most succinct description of the economic problem that I have come across comes not from a practicing economist, but from a scientist concerned about tropical ecosystem degradation. In a recent address to a coral reef symposium, Nancy Knowlton of the Smithsonian Tropical Research Institute called on improved interdisciplinary studies between biology and economics to help solve some of the hard decisions that need to be made in coral reef management. She states:

> In order to defend reefs economically, the marginal costs of reducing stress on reefs must be less than the marginal benefits associated with so doing. Calculating the economic costs of treating sewage, not fishing, or not building are fairly straightforward, and have been used for years to support policies that are detrimental to reefs. More recently, economic analyses of the benefits associated with maintaining or improving the health of reefs have made important strides. To use such analyses, however, we need to make biological as well as economic assumptions. … While it is tempting to assume simple biological relationships, such assumptions are rarely if ever justified.
>
> (Knowlton 1998, p. 183)

The economic challenge is thus to address both the costs and benefits of reef management, within a context of ecological complexity. Unfortunately, many economic modeling efforts fail to address complexity issues, and may therefore provide incorrect advice. It is quite likely that the only manner to address such issues is on a case-by-case, site-by-site basis using careful empirical studies.

In essence, the basic concern of environmental economics in this context is "What is the price of a coral reef?" By price, we must interpret this as the *marginal change in benefits* from an additional unit of coral reef; this definition is critical in our understanding of coral reef economics, is consistent with basic constructs of welfare economics, and is the relevant framework for informing policy decisions. To use shorthand from the literature, this price is what we call a "planning price." If we have such planning prices in hand, we might juxtapose them in a cost-effectiveness analysis or use them directly in cost-benefit analyses. They may also inform policy decisions relating to user fees, to the tightening of regulations, or to the implementation of common property management regimes. But estimating such prices, and doing so within an appropriate policy framework, is easier said than done.

A First Attempt at Valuing SE Asia's Coral Reefs

When faced with limited time and resources, it has become fashionable of late to rely on a benefit transfer approach to determine a price or a value. Let us embark on such a route.

In a seminal piece by Costanza *et al*. (1997, 1998), the value of all global ecosystems was estimated to be some US$33 trillion annually. Inspection of the results (Table 3) reveals that coral reef ecosystems contributed about US$375 billion annually, based on an annual value of US$6,075/ha applied to 62 million ha of coral reefs (in 1994$). Given that SE Asia's coral reefs comprise about 30% of the global total, a benefit transfer approach – such as that employed by Costanza and colleagues – would yield a value of US$112.5 billion annually. If we wished to do some fancy fine tuning of this number to generate a higher and more impressive number for policy makers, and to convince people that our economics degrees were well-earned, we might further escalate this annual value to account for global inflation, and then convert

Table 3. Coral reef average values from Costanza *et al*. (1997, 1998).

Function	1994 US$/ha/yr
Climate Regulation	n.e.
Disturbance Regulation	2750
Erosion Control	n.e.
Nutrient Recycling	n.e.
Waste Treatment	58
Biological Control	5
Habitat/Refugia	7
Food Production	220
Raw Materials	27
Genetic Resources	n.e.
Recreation	3008
Culture	1
Total	6075

it into a single present value using an appropriate discount rate. If, for instance, we assume annual increases in value from 1994 to 1999 of 5%/yr, and applied a 10% discount rate to convert the annual amounts into a single present value, the arithmetic readily shows that this undersea treasure in SE Asia is worth just over US$1.4 trillion.[5]

But what, in fact, does this number mean? More to the point, is it likely to be correct and, if so, how is it useful for policy purposes?

The first flaw would be one proffered by the authors themselves: they would regard this as a "lower estimate" as it ignores many of the values that were not explicitly estimated (marked as "n.e.") during their review of the literature in deriving the various functional values. No studies of genetic resource values, for example, were available to them. Work by Ruitenbeek and Cartier (1999) calculated genetic resource values in a range of US$7,500/ha/yr to US$500,000/ha/yr for coral reefs in Montego Bay, Jamaica; if these were transferred "as-is" to the current estimate, it could potentially increase the value by as much as two orders of magnitude.

A second flaw is that the various estimates contained in Table 3 are themselves not necessarily consistently done. An audit of the sources of data would reveal that some are gross values while others are net values; tourism and fishery studies are especially notorious for neglecting all of the social costs. But from a valuation and planning perspective, we are usually most interested in the net values as they provide an indicator of economic efficiency. Any values derived based on Table 3 would thus be over-estimates.

A third flaw relates to one of "inappropriate extension" of prices. In many cases, this error is not usually that obvious but – in the case of coral reefs – the error is much more obvious and readily shown by example. Essentially, we must ask, "How likely is it that every coral reef in the world would generate similar levels of tourism and recreation benefits as those currently studied?" As noted in Table 3, recreation values are estimated to be US$3000/ha/yr; the literature on which this estimate is based draws on studies from premier sites such as Key Largo (Florida), the Great Barrier Reef, and Bonaire Marine Park. But it is highly unlikely that every site in the world would attract the same level of benefits; such an extrapolation, or extension, is clearly unrealistic and obviously over-estimates any resultant value.

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[5] Computed as US$112.5 billion x 1.05^5 x (1/0.1) = US$1435.8 billion.

Finally, in my view, one of the most critical flaws is that the benefit transfer does not distinguish between marginal values and average values. The US$1.4 trillion calculation is an average value applied to coral reefs measured in terms of hectares. In reality, one hectare can not be treated the same as any other hectare, and the value of one hectare may itself be dependent on what has occurred on other hectares. This is most easily seen through the effects of substitutability: if one reef is damaged, tourists (and fish) might readily flock to another reef area and enjoy a similar level of services. In the realm of genetic prospecting, it is well known that there is less endemism in marine areas than in terrestrial areas, because of the wider range of transport mechanisms available in water; analyses of species-area relationships, for example, shows that a 50% reduction in coral reef area would result in a reduction of 13% to 19% in species (Ruitenbeek and Cartier 1999, based on Reaka-Kudla 1997). On the other hand, it may also be the case that a small reduction in reef quality would cause the complete loss of a tourism industry if there are no locally available substitutes (Gustavson 1998); in such a case the marginal values are much greater than the average values that one might find in a benefit transfer calculation. In short, there is no reason to believe that average values will necessarily be equal to, greater than, or less than, marginal values; as local planning prices will *always* depend on marginal values, however, reliance on average values is unlikely to provide any meaningful basis for policy formation.

Given these flaws, about all we can say from our benefit transfer analysis is that the value of SE Asia's coral reefs is either greater than or less than US$1.4 trillion.

Lessons from the Empirical Literature

If the global approach can not give us the information we require, it is clear that we must rely on site specific work. Very little has, in fact, been done in SE Asia; Table 4 provides a complete listing of empirical environmental economics studies in SE Asia, plus two others to demonstrate some analytical points for functions that are not at all covered by any studies in SE Asia (these include education values and valuation of marine genetic resources). I shall here provide a synopsis of the studies undertaken to date, concentrating on key lessons learned from such studies.

The studies reviewed here are all benefit valuation studies. I note that there is also substantial interest in undertaking cost-effectiveness analyses (CEA); and Nancy Knowlton in the opening quote to this chapter implies that such analyses are relatively routine. In fact, I would argue that this is far from the case, and that CEA requires the same attention to complexity that she advocates for other types of analyses. The basic idea behind CEA is to look at the impacts of different intervention options on reef quality, and to select the least cost alternatives before the high cost alternatives. No studies of this type have been conducted in SE Asia, and few rigourous studies have been undertaken anywhere. Recent findings by Ruitenbeek *et al*. (1998, 1999), using fuzzy logic techniques to model dose-response functions, conclude that in non-linear systems such as coral reefs one can not necessarily assume that a low cost intervention at one reef quality level will mean a low cost intervention at a different reef quality level. This result places in question the validity of cost-effectiveness analysis unless it is accompanied by benefit valuation to assist in identifying a local optimum.

Harvested Products

Studies involving harvested products from coral reef habitats are among the most common found in the region; all of the valuations use a change in productivity approach with varying degrees of linkage complexity. The study by Driml (1999) does not incorporate ecological economic linkages: the valuation simply represents the gross financial value of harvested products. The other studies (Cesar 1996, Hodgson and Dixon 1988, McAllister 1988, Sawyer 1992) try to link reef quality to fishery productivity: reef quality is viewed as a factor of production, a change in which leads to a change in reef productivity; the productivity change is measured in terms of output levels. These approaches rely on quantitative ecological analysis and ecological economic linkages.

Three types of weakness are often evident in these types of valuations. First, and most serious, is that fisheries value is usually assumed to be its gross revenue, thus ignoring the opportunity cost of capital and labor in fishing effort. Such gross value estimates for fisheries over-state the net benefits from such activities and often make it politically difficult to find other economically benign and sustainable uses of a reef area. Second, the dynamics of the coral reef and surrounding natural systems are often simplified, if not ignored. Third, a less obvious weakness of many of these approaches is that they usually base harvest rates on some level of extraction effort which is implicitly assumed to be value-maximizing. In the simplest cases, current (observed) extraction rates are assumed to occur in perpetuity, even though these may be either above the socially optimal rate (from the usual types of over-fishing practices) or, more rarely, below the optimal rate (e.g., where there are barriers to entry). Some analysts are more careful about this aspect of extraction, and base their assessments on maximum sustainable yield (MSY) to introduce some form of sustainability constraint (Cesar 1996). Even in such cases, however, it is important to note that MSY does not necessarily coincide with an economic optimum; standard fishery economics teaches us that it may be economically optimal to extract at rates either below or above the MSY depending on the attributes of the specific fishery. In cases where current harvest rates are used, it is likely that the methods over-estimate value; while estimates based on MSY will likely underestimate economic value.

Tourism and Recreation

Recreation is often cited as the most significant economic function of coral reefs. Three approaches to estimating value are usually evident: change in production, contingent valuation methods (CVM), or travel cost methods (TCM). The change in production value approach is used by Driml (1999) for the Great Barrier Reef, Cesar (1996) for Indonesia, and Hodgson and Dixon (1988) for Bacuit Bay, Philippines; but all take the gross revenue approach. From a utility perspective, these values ignore the consumer surplus generated by the recreation experience and as a result underestimate the value of the recreation experience. From a production perspective, gross tourism revenue ignores the labor and capital costs of supplying the services, as well as the costs associated with the environmental impacts of tourism. Inclusion of such costs, as is done by Gustavson (1998), is required to obtain a fair estimate of production values.

Consumer surplus value estimates have been undertaken in the region only through one set of studies by Hundloe *et al*. (1987), who employ both TCM and CVM to generate estimates of reef value by explicitly defining a “reef region.” An important component of this work is that the analysts generate distinct values for coral reefs; other CVM studies of tourist value (Dixon *et al*. 1993) often fail to distinguish between tourism value as a whole or tourism value attributable to just the reef.

Erosion Control

Of the numerous unmarketed ecological functions performed by coral reefs, coastal erosion control has received the greatest attention. Two studies from SE Asia serve to illustrate the different methods employed: one focuses on the replacement cost of the reef; while the other focuses on the value of the land that the reef protects.

McAllister (1991) estimates the protection function value of coral reefs in the Philippines by calculating the costs of replacing the reefs with artificial devices to protect the coast. This type of calculation is considered to be a minimum estimate of the protection value afforded by reefs because: (i) delayed response time could mean that terrestrial productivity is lost in the interim; and, (ii) artificial devices will forever need maintenance. The estimate obtained by McAllister is based on the per unit area cost of installing a certain type of barrier (concrete tetrapod devices) and multiplying that unit cost by the length of coastline fringed by coral reefs. The estimate does not allow for variations in the protective requirements along the coastline, given varying rates of coastal erosion and levels of economic activity. A major detriment to this replacement cost approach is that it begs the policy question of whether the reef in fact provides any protective value, and the amounts so calculated do not provide a basis for policy formulation.

For Indonesia, Cesar (1996) uses CBA to compare the potential value of the coastal protection function of a coral reef, to its value as it succumbs to the impacts of blast fishing and coral mining. The protection function reflects the value of onshore land, either through market land values, through costs of replacing important infrastructure or crops and housing, or some combination of these. The CBAs treat blast fishing and coral mining separately; the hypothetical reef faces only one threat at a time. In each analysis, the value of the societal loss of the reef's protective function is the decline in the potential value of the protective function as the reef is destroyed. The yearly losses in protective function value are based on threat-specific assumptions regarding the rate of reef destruction, the point at which the level of destruction starts to impair the ability of the reef to provide coastline protection, and the ability of the reef to recover. An important contribution of this analysis is that it underlines the need to make connections between the reef threats (e.g., blast fishing), the reef's physical response, and the economic production that the reef allegedly protects.

Education and Research Values

Only a handful of such valuation studies have been undertaken worldwide, and none in SE Asia. Gross financial expenditures are typically used to estimate the education and research value of coral reef habitats. The expenditures include food, lodging, and fees for researchers and educators; boats and diving gear; research/education facilities and equipment. As an example, Spurgeon (1992) places values on the education and research value of coral reefs in Panama and Belize, based on coral reef budget allocations of research-funding institutions in the US and UK.

An inherent weakness of all of these studies, which base their methodologies on expenditures estimates, is that they simply provide a measure of direct economic impact and say little about the efficiency of such expenditures or of the optimal level of such expenditures. Their connection to economic benefits is somewhat specious, although they may to some degree be construed as some revealed willingness to pay for having access to a particular reef area of research interest.

Marine Genetic Prospecting

One of the most complex use values to estimate, for either terrestrial or marine ecosystems, relates to genetic prospecting. Only a handful of such studies have been undertaken for terrestrial systems, and a study of the Montego Bay Marine Park by Ruitenbeek and Cartier (1999) represents the first such study to be undertaken of any marine system. A key conclusion of this work is that the marine system values and planning prices are extremely sensitive to assumptions about: (i) local institutional arrangements to capture genetic values; (ii) assumptions relating to species-area relationships; and, (iii) assumptions relating to ecosystem sampling yield. Within plausible ranges of parameters for all of these, planning prices could vary by as much as three orders of magnitude.

Non-use Values

Only one study in the region estimated a combined option and existence value for a coral reef habitat. Hundloe *et al*. (1987) uses CVM to estimate the value of coral sites within the Great Barrier Reef to “vicarious” users. From adult Australian citizens, willingness-to-pay (WTP) bids to ensure that the reef is maintained in its (then) current state are used to calculate a consumer surplus of A$45 million a year. Bids from survey respondents who had visited the reef are excluded, but the motives behind bids from non-users were not distinguished. Therefore, although the estimate represents non-use value, it does not separate option and existence values. In any case, the authors stress that the valuation is an underestimate because it excludes the vicarious value of the reef to overseas residents.

More recent CVM studies of non-use benefits of Caribbean coral reefs (Spash *et al*. 1998) have underlined the importance of further probing respondents for reasons behind their answers. Using such techniques, one can distinguish between different reasons for giving "zero bids"; methodologically, distinguishing between such zero bids is perhaps the greatest source of uncertainty in the coral reef CVM literature.

Summary – Just Say "No" to Benefit Transfer

A key lesson from the applied literature is that environmental economics analysis of coral reef ecosystems requires careful case by case analysis that addresses local system complexities. Benefit transfer techniques generally fail to recognize such local nuances. The literature suggests that researchers must:

- <u>pay attention to net benefits generated by local marketed uses</u>. This is especially critical for fisheries and for tourism and recreation. Many existing studies simply ignore the costs of recreational activities, or the costs of harvesting effort.
- <u>isolate the reef benefits from other benefits</u>. Especially when measuring consumer surplus, care must be taken to isolate the marginal effects of the reef system and not necessarily lump the effects of the reef with other ecosystems.
- <u>focus on planning prices within a context of system complexity</u>. Primarily, this implies that one should not assume linear relationships between such simple indicators as coral reef area, and of the functions and values that are supported by coral reefs. Marginal values do not necessarily equate to average values. Small changes in reef quality or extent may have proportionately larger or proportionately smaller impacts on the values that the reef supports.
- <u>consider the institutional angles</u>. Local institutional considerations can have dramatic effects on values. Conditions of open access may create rent dissipation (and zero values if estimates are based on current harvesting levels and effort), even though a sustainable management regime might generate substantial positive values. Also, for non-use values or genetic prospecting values, institutional arrangements may be inadequate for local stakeholders to capture even a small share of what may be a large global value.

In brief, the complexity inherent in coral reef ecosystems translates into a complexity inherent in doing environmental economic analyses of such ecosystems. One must keep in mind that any particular research result is likely to be only one among many inputs to a dynamic decision-making complex. It is certainly no accident that many analysts are opting to use multi-criteria decision-making tools for coral reef management problems (Adger *et al*. 1999), with environmental economics as one component of such an analysis.

Table 4. Coral reef related valuation studies from SE Asia and Great Barrier Reef.

Source: based on Cartier and Ruitenbeek (1999).

Valuation Type and Original Study	Valuation Results	Miscellaneous Notes including Secondary Sources
Direct Use Values for Marine Areas – Harvested Products		
Fisheries Valuation Great Barrier Reef (Driml 1999)	Productivity Change: Gross Revenue A$143 million (1996); based on 1995/96 catch data for major commercial species, and a survey of current fish prices.	Study updates Driml (1994) estimates presented in Driml (1997) and Driml *et al.* (1997).
Fisheries Valuation Bacuit Bay, Philippines (Hodgson & Dixon 1988)	Productivity Change: PV Gross Revenue $9108 with logging vs $17,248 with logging ban; based on assumed constant returns to scale of natural systems; and on regression analyses of sediment loading, coral cover and species, and fish biomass relationships.	CBA study evaluates management options: (i) continuation of logging as usual; (ii) logging ban in Bacuit Bay drainage basin.
Fisheries Valuation, Taka Bone Rate Coral Reef Atoll, Indonesia (Sawyer 1992)	Productivity Change: PV Gross Revenues (billion Rp): -2 to 103 without management vs 47 to 777 with management; based on fishing activity surveys; and sensitivity analyses wherein fish catch declines range 0-15% and discount rates vary 5-15%.	CBA study evaluates management options: (i) no management; (ii) establishment of marine park with regulated fishing.
Fisheries Valuation, Indonesia Coral Reefs (Cesar 1996)	Productivity Change: NPV of fisheries loss/sq km of reef: $40,000 (poison fishing); $86,000 (blast fishing); $94,000 (coral mining); $81 (sedimentation); $109 (overfishing); based on assumptions about the reef and fishery impacts of these practices.	Study uses CBA to compare the private and social net benefits of a sustainably managed reef fishery, with those of a fishery subjected to detrimental fishing practices, coral mining, or sedimentation.
Fisheries Valuation, Philippines (McAllister 1988)	Productivity Change: $80 million/yr in lost fish production caused by dynamiting, muro-ami, and poisoning of coral reefs; based on estimates of current and potential production.	Production levels are calculated for varying levels of reef damage.
Aquarium Trade, Philippines (McAllister 1988)	Productivity Change: Global aquarium trade attributable to the Philippine Coral Reefs: $10 million in 1988 could be increased by 50% with sustainable production practices.	The price of Philippine aquarium species is discounted internationally due to method of capture.
Direct Use Values for Marine Areas - Recreation & Tourism		
Recreation Value Great Barrier Reef (Driml 1999)	Productivity Change: Gross Recreation Value A$769 (1996), includes A$647 for commercial tourism and A$123 for recreational fishing & boating; based on volume & price data for hotel stays & reef trips, and survey data for private recreational boat use.	Study updates Driml (1994) estimates presented in Driml (1997) and Driml *et al.* (1997).
Visits to Great Barrier Reef "Region" (Hundloe *et al.* 1987)	TCM: A$144 million/yr consumer surplus for domestic tourists and international tourists; based on travel cost expenditure by visitors to the "Reef Region."	As reported in Hundloe (1990).
Visits to Coral Sites and the "Reef Region" of the Great Barrier Reef (Hundloe *et al.* 1987)	TCM: A$106 million/yr consumer surplus; based on travel costs to coral sites by both domestic and international tourists, and includes all attributes of the "Reef Region."	As reported in Hundloe (1990).
Visits to Coral Sites within the Great Barrier Reef (Hundloe *et al.* 1987)	CVM: A$6 million/yr consumer surplus or over A$8/adult visitor WTP to see coral sites in their present (1986-87) condition; based on a survey of visitors to reef sites only, thereby excluding all other attributes of the Great Barrier Reef "Reef Region."	As reported in Hundloe (1990) and Driml *et al.* (1997).
Tourism Palawan Coral Reef, Philippines (Hodgson & Dixon 1988)	Productivity Change: PV gross revenue $6,280 with logging vs $13,334 with logging ban; based on mean hotel capacity, occupancy, and daily rates; and an assumed 10% annual decline in tourism revenue due to degradation of seawater quality from sedimentation.	CBA study evaluates management options: (i) continuation of logging as usual; (ii) logging ban in Bacuit Bay drainage basin.
Tourism Valuation, Indonesia Coral Reefs (Cesar 1996)	Productivity Change: NPV of tourism loss/sq km of reef $3000-436,000 (from poison fishing); $3000-482,000 (blast fishing or coral mining); $192,000 (sedimentation); based on assumptions regarding the rate of reef degradation associated with each practice.	CBAs for each reef-destroying activity estimate the value of tourism loss. For each activity, reef degradation causes a decrease in potential tourism revenue. All rates of change are based on assumptions.

Table 4. Coral reef related valuation studies from SE Asia and Great Barrier Reef.

Source: based on Cartier and Ruitenbeek (1999).

Valuation Type and Original Study	Valuation Results	Miscellaneous Notes including Secondary Sources
Education & Research - Marine Areas		
none in SE Asia		
Panama Coral Reefs (Spurgeon 1992)	Expenditures: \$2.5 million in 1991; based on a percentage of the Smithsonian Research Institute's budget for work in Panama.	One-sixth of the 1991 \$15 million budget is considered attributable to coral reefs in Panama.
Indirect Uses - Ecological Functions		
Coastal Protection, Philippine Coral Reefs (McAllister 1991)	Replacement Costs: US\$22 billion; based on construction costs of concrete tetrapod breakwaters to replace 22,000 sq km of reef protection.	As reported in Spurgeon (1992).
Coastal Protection, Indonesia Coral Reefs (Cesar 1996)	Productivity Change: NPV of coastal protection/sq km of reef: \$9000-193,000 (blast fishing); \$12,000-260,000 (coral mining); based on replacement costs, the rate of reef destruction from each activity, and the rate of decline in reef's ability to protect.	CBAs for each reef-destroying activity include the cost of protective function losses. For each activity, reef destruction reduces the protective capability of the reef. The reef's loss of protective capability is linked linearly to its protective value.
Genetic Resources - Marine Systems		
none in SE Asia		
Value of Pharmaceuticals from Coral Reefs (Ruitenbeek & Cartier 1999)	Value of Montego Bay coral reef based on model incorporating drug values, local bioprospecting costs, institutional costs, discovery success rates for marine extracts, and a hypothetical bioprospecting program for the area using National Cancer Institute sampling protocols. Model highlights role of revenue sharing arrangements and ecosystem yield in deriving total benefits and marginal benefits. Average Net Social Value of species in base case is estimated to be \$7775. Based on base case sampling program, total social NPV of Montego Bay reef area is US\$70.09 million. First differential of the benefit function yields US\$225,000/% or US\$530,000/ha coral abundance.	Authors note sensitivity of results to assumptions in ecosystem yield and species-area (SA) relationships, which relied on SA estimates by Reaka-Kudla (1997) for global coral ecosystems. In base case $S=cA^z$, z=0.265. Within potential range of z=0.2 to z=0.3, NPV shifts from \$85 million to \$54 million and marginal benefit shifts from \$72,500/ha to \$698,000/ha. Summary available at: http://www.island.net/~hjr
Option & Existence Values		
Existence and Option Value, Great Barrier Reef (Hundloe *et al.* 1987)	CVM: A\$45 million/yr consumer surplus or A\$4/visit WTP to ensure that the Great Barrier Reef is maintained in its current state; based on a 1986 mail survey of Australian citizens 15+ yrs old; estimate excludes respondents who had visited the Reef.	As reported in Hundloe (1990).

Chapter 4
General Research Implications for EEPSEA

"THAT THE AUTOMOBILE HAS REACHED the limit of its development is suggested by the fact that during the past year no improvements of a radical nature have been introduced."

– Scientific American. 2 January 1909.

When research comes to a standstill, few improvements will come forth. Whether one is designing a better automobile, looking for a more effective drug, or trying to improve coral reef management, basic and applied research will play an important role. In this chapter, I outline a number of potential study types that might be feasible within the usual EEPSEA 12-18 month study timeframe. Also, to address the more complex areas that might take longer, I suggest a few potential research topics that might warrant consideration as part of EEPSEA's support for thesis research.

A Sampling of Potential Research Projects

In all cases, research projects must address a local policy problem. In the case of coral reefs, this will in many instances involve a need for institutional strengthening; valuation can play an important role in drawing policy-maker attention to the value of protecting reefs or managing them better. In addition, as noted in Chapter 2, the research can be used to identify appropriate policies for controlling land-based pollution, for limiting the over-harvesting of products, or for reducing resource use conflicts.

Study Type 1 – Single Site Direct and Indirect Use Valuation

This study concentrates on the "change in productivity" techniques of valuation, and finds counterparts in many terrestrial research projects. Of the three studies outlined here, it is the simplest. It addresses policy problems such as: (i) tradeoffs between different resource uses; and, (ii) awareness building relating to untraded uses. The study can include a full cost-benefit analysis if the system is limited to a few well-defined alternative uses (such as local harvesting and tourism), or it can be limited to valuation of high priority uses if the main policy purpose is awareness building.

Research techniques for conducting this type of analysis can rely initially on focus groups and secondary literature searches to identify the key traded and untraded uses to be valued.[6] To provide consistency with the existing literature, the most likely categories of use will include: (i) commercial fishery; (ii) local harvesting of untraded goods; (iii) recreation and tourism; and, (iv) erosion control. Subsequent data collection is likely to rely on standard surveys for harvesting activities, and use of government or industry statistics for tourism and erosion control values.

The primary methodological challenges involved in such research will include: (i) collecting relevant cost information to insure that net benefit estimates are made; (ii) collecting adequate appropriate biophysical information about the reef environment to permit relevant ecological linkages to be identified; and, (iii) obtaining reliable information relating to what in some cases may be illegal activities.

Study Type 2 – Multi-site Comparative Studies of Recreation Values

A somewhat more complex study would involve a multi-site comparison of recreation uses, relying on contingent valuation or travel cost methods. Where institutional structures are weak, a study of this sort could assist in addressing a policy question of the sort, "Does it make sense to establish (or enforce) coral reef MPAs?" Where existing institutions are stronger, such a study could help establish appropriate fee structures and levels for a park system.

Research techniques for conducting this type of analysis will rely on structured CVM and TCM surveys (Hundloe *et al*. 1987). These are normally developed through focus groups, and are pre-tested before being administered to a cross-section of resource users. Attribute analysis is subsequently undertaken using appropriate statistical methods, with a view to isolating the values that people attach to various characteristics of the recreation experience.

The primary methodological challenges involved in such research will include: (i) finding a cross-section of sites that have adequately different attributes such that respondents can discern between site choices; (ii) finding reliable travel cost information in an economically volatile environment; and, (iii) separating the "reef region" attributes from other attributes that may contribute to the valuation problem.

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[6] A number of studies are relevant to this type of exercise; the reader is refered to Table 4 and to the literature survey conducted by Cartier and Ruitenbeek (1999).

Study Type 3 – Single- or Multi-Site Contingent Valuation of Non-use Values

This study is analytically the most complicated of the studies presented here, as it focuses on non-traded values and requires using a CVM approach to elicit bids relating to coral reef quality or value. Such analyses can be instrumental in determining whether it makes sense to establish MPA systems, or a specific MPA.

Research techniques for conducting this type of analysis will rely on structured CVM surveys (Hundloe *et al*. 1987, Spash *et al*. 1998). These are normally developed through focus groups, and are pre-tested before being administered to both residents and visitors. Bid-curve analysis is a complicated procedure that, in the case of coral reefs, will rely on the use of qualitative dependent variable statistical techniques; any researcher attempting such a study should therefore have strong statistical analysis skills.

The primary methodological challenges involved in such research will include: (i) providing adequate information to respondents relating to local coral reef conditions; (ii) designing appropriate probing questions to allow analysis of "zero" bids, which can make up one-third of responses; (iii) insuring that the non-use values do not inadvertently include some direct or indirect use values; and, (iv) finding a basis for translating the WTP bid-curve information into a total value estimate that can be applied to a given reef site. Also, in some cases, it may be necessary to provide some benchmark value against which this can be compared; such a benchmark would most usually include some readily estimated direct use (e.g., fishery or tourism).

Some Thesis Research Challenges

All of the above projects can be undertaken within a one year period by a team familiar with the environmental economics approaches used within EEPSEA. For those with more time and resources, other research opportunities present themselves. These generally stand out from those above because they require greater methodological development (i.e., they do not replicate existing studies), they have unusually expensive research requirements (i.e., prolonged data gathering) or they have greater interdisciplinary requirements (i.e., they require inputs from non-economists for at least one-third of the work). Such projects include:

- <u>environmental economic analysis of coral reef institutional management options</u>. Such an analysis provides a comparative assessment of the economic, ecological and social impacts of different institutional arrangements (usually open access vs common property vs private property) for managing coral reef resources. There is no template for conducting such an analysis, and hence requires methodological development along the lines found for terrestrial management problems (e.g., grazing lands). The analysis is complicated by the fact that jurisdiction over marine resources is often even less clear than it is for terrestrial resources (see also Bromley 1997).

- cost effectiveness analysis of coral reef management options. Such a project addresses the policy question of "What is the optimal mix of investments to reduce land-based pollution and sedimentation impacts on coral reefs?" It follows work by Meesters *et al*. (1998) and Ruitenbeek *et al*. (1998, 1999), relying extensively on biological and oceanographic information to develop dose-response functions that can be linked to economic cost models.
- biological prospecting valuation. Such studies address the economic values of a heretofore untraded good. Although templates now exist for such studies (Ruitenbeek and Cartier 1999), data requirements are onerous for the typical EEPSEA research project. Minimally, information relating to local species inventories and bioprospecting rates is required, along with local cost information. Because of the nature of the industry, such information is typically purchased under confidentiality agreements and often requires further analysis by non-economists to insure that the data are not being misinterpreted.

Closing Comments

Research in the field of coral reef economics is not likely to be easy. If well thought out, though, valuation research can make important contributions to coral reef management. My previous experience with researchers in EEPSEA is that, when developing a research proposal, they will initially take on more than they can reasonably do within the timeframe and budget of a research project. My intuition is that the same will hold true in the case of coral reef research; there will be a temptation to answer all of the policy questions inherent in coral reef management at a given site. It is tempting to try to answer completely questions such as "What is the best economic mix of all coral reef uses?" or "What is the economically optimal level of reef use or reef quality?" While such policy questions can be the driving force in research, I would advocate that any given piece of environmental economic research should focus on smaller parts of the puzzle. I can guaranty that *any* valuation work done in SE Asia will receive international prominence if it is done well. There remains a dearth of empirical studies relating to marine systems. But in filling such a void, there is also a responsibility to do so using careful analyses and state of the art techniques.

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Internet Links Relating to Coral Reef Management

Sponsor	Internet Address (URL)
Australian Institute for Marine Science	www.aims.gov.au/ibm/
Center for Marine Biotechnology and Biomedicine (CMBB)	sio.ucsd.edu/supp_groups/development/cmbb.html
Coastal Resources Center (Rhode Island)	crc.gso.uri.edu
Coral Reef Alliance (CORAL)	www.coral.org
Coral Reefs (Journal)	link.springer.de/link/service/journals/00338/index.htm
Intergovernmental Oceanographic Commission	ioc.unesco.org/iocweb
International Center for Living Aquatic Resources Management (ICLARM)	www.cgiar.org/iclarm/ [includes ReefBase]
International Coral Reef Initiative (ICRI)	www.gbrmpa.gov.au/~icri/
NOAA Coral Health and Monitoring Program (CHAMP)	coral.aoml.noaa.gov/
Reef Check	www.ust.hk/~webrc/ReefCheck/reef.html
Ruitenbeek Coral Page	www.island.net/~hjr
World Conservation Monitoring Centre	www.wcmc.org.uk
World Resources Institute "Reefs at Risk"	www.wri.org/indictrs/reefrisk.htm