Final Report

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Economic Valuation of the Coral Reefs of Hawaii

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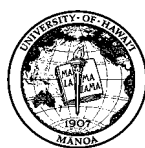
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COASTAL
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PROGRAM

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Abbreviations

CBA	=	Cost Benefit Analysis
CVM	=	Contingent Valuation Method
ERR	=	Economic Rate of Return
DAR	=	Division of Aquatic Resources
FRA	=	Fish Replenishment Area
FRR	=	Financial Rate of Return
FY	=	Fiscal Year
GIS	=	Geographical Information System
HCRI	=	Hawaii Coral Reef Initiative
MHI	=	Main Hawaiian Islands
N/A	=	Not Applicable
NWHI	=	Northwest Hawaiian Islands
NPV	=	Net Present Value
O&M	=	Operation and maintenance
TCA	=	Travel Cost Approach
VAT	=	Value-added tax
WTP	=	Willingness to Pay

Acknowledgements

Executive summary

According to the Hawaiian Hymn of Creation, the coral polyp was the first creature to emerge during creation. This can hardly be a coincidence, since Hawaii is exceptionally well endowed with coral reefs. Around 85 percent of potential reef area of the United States is within the Hawaiian Archipelago. The majority of this area is located in the Northwest Hawaiian Islands (8,521 km^2 or 2.1 million acres). The Main Hawaiian Islands have 2,536 km^2 (627,000) of potential reef area with 1660 km^2 (410,000 acres) under the jurisdiction of the State of Hawaii (see Table E-1). The Main Hawaiian Islands host 60 known species of hard corals with over 25% endemism. Live coral cover is on average 18% for all sites surveyed under the Hawaii Coral Reef Assessment and Monitoring Program (CRAMP). There are thought to be over 400 species of marine algae and even more species of reef and shore fishes, mollusks and crustaceans. The Hawaiian Archipelago has a combination of fringing reefs, barrier reefs, atolls and reef communities.

Table E-1: Summary on data of the Hawaiian Islands

	Land area (km^2)	Reef area (km^2) [0-3 naut.miles]	Reef area (km^2) [3-200 naut.miles]	Total reef area (km^2)
Main Hawaiian Islands (MHI)				
- Hawaii	10,433	252	0	252
- Maui	1,884	270	0	270
- O'ahu	1,546	504	0	504
- Kauai	1,431	266	0	266
- Moloka'i	673	128	870	998
- rest Main Hawaiian Islands	660	236	10	246
Total Main Hawaiian Islands	*16,627*	*1,656*	*880*	*2,536*
Northwest Hawaiian Islands	*15.4*	*2,430*	*6091*	*8,521*
Total Hawaiian Archipelago	*16,642*	*4,086*	*6,971*	*11,057*

Source: Gulko et al. (2002)

Although the coral reef area of the Main Hawaiian Islands is smaller, its economic importance outweighs that of the Northwest Hawaiian Islands. For example, the annual number of visitors to the Main Islands is 11 million while the Northwest Islands receive only 5000 visitors per year. Given this significant contrast and the large differences in data availability, our study focused solely on the Main Hawaiian Islands.

Coral reefs are essential for the livelihood of many Hawaiians, both through the provision of tourism and fisheries. Furthermore, reefs dissipate wave energy and thereby protect coastal infrastructure, tourist beaches and communities. Because of their unique biodiversity, they are of great interest to scientists, students, pharmaceutical companies, and others. In addition, coral reefs have traditionally played an important spiritual and cultural role. These and many other functions give coral reefs a substantial socio-economic value in Hawaii.

Various anthropogenic activities in Hawaii negatively impact coral reefs and jeopardize the benefits provided by their services and goods. Threats include overfishing, excess

nutrients, invasive algae, sedimentation, and tourism pressure. These threats result from lack of awareness, market failures, undervaluation of resources and insufficient enforcement of protective legislation. In Hawaii, the traditional *Ahupua'a* concept saw the entire watershed from hilltop to reef (and beyond) as one area to be managed by one group. This ensured that any impacts of land-based activities on coral reefs were taken into account. Unfortunately, this concept has been eroded due to modern state-level planning and the cash-economy.

Economic valuation can help facilitate the Hawaiian concept of integration. It does this by highlighting the costs of ignoring inter-dependencies and by quantifying the importance of reef services in monetary terms. It can therefore play a crucial role in communicating the importance of reefs to Hawaii's people and policy makers. Moreover, economic valuation helps with natural resource damage assessment, for instance, in case of oil spills, ship groundings, sediment dumping, etc. Finally, it can provide an economic basis for financial commitments by the State and Federal government for coral reef management. In this light, the objective of the study is threefold: *(i) to assess the economic value of selected case study areas (see below) and of Hawaii as a whole, (ii) to determine the economic costs of reef degradation; (iii) to compare the costs and benefits of various management options which aim to reverse these trends.*

As indicated on the map in Figure E-1, the following case study sites were analysed:

1. Hanauma Bay (O'ahu), addressing tourist overuse;
2. Kihei and Ka'anapali (Maui), addressing excessive nutrients and algae blooms;
3. Kona coast (Hawai'i), addressing overfishing;
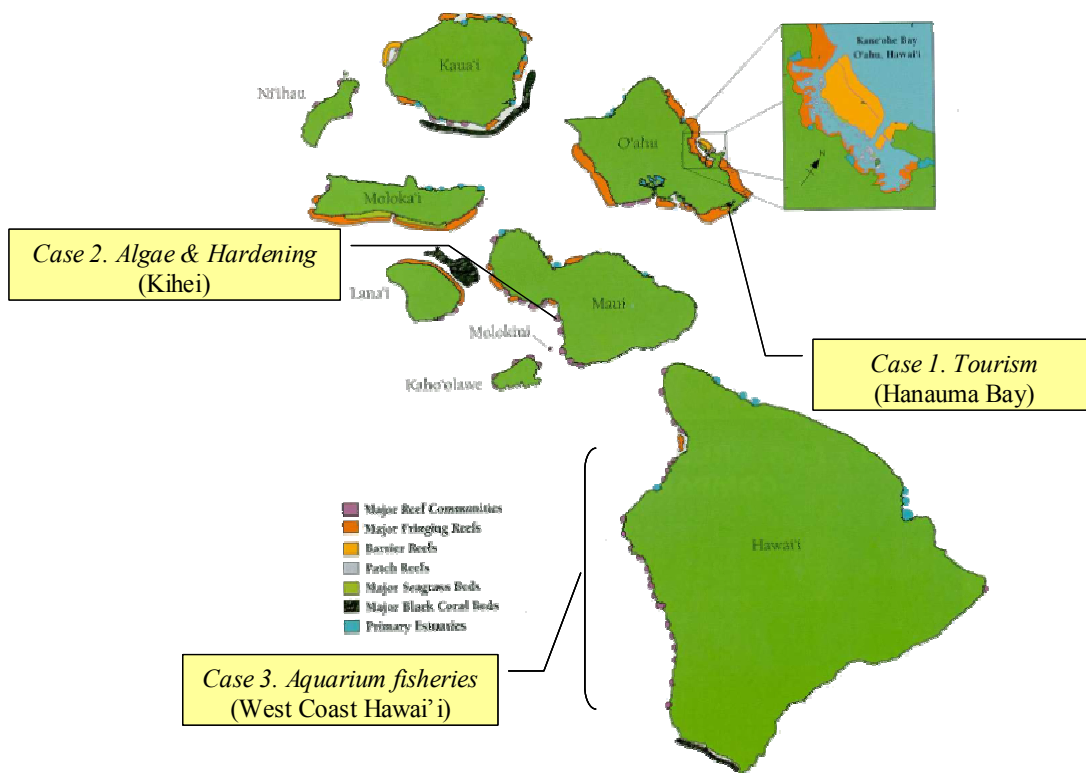
Figure E-1: Map of the Main Hawaiian islands and the selected case studies

An integrated model developed under this project forms the basis of the analysis. This model, referred to as SCREEN (Simple Coral Reef Ecological Economic Model), links ecology and economy in a dynamic manner. Figure E-2 highlights the key features of this model and the interactions between different ecological and economic components. It also shows the threats and their impact on ecological factors, as well as the necessary interventions required to mitigate these threats. Finally, the associated costs and benefits of the interventions are displayed. The model uses a 25-year period (2000-2025); this leaves enough time for the main ecological outcomes to come into effect, while being short enough to allow for predictions about future developments.
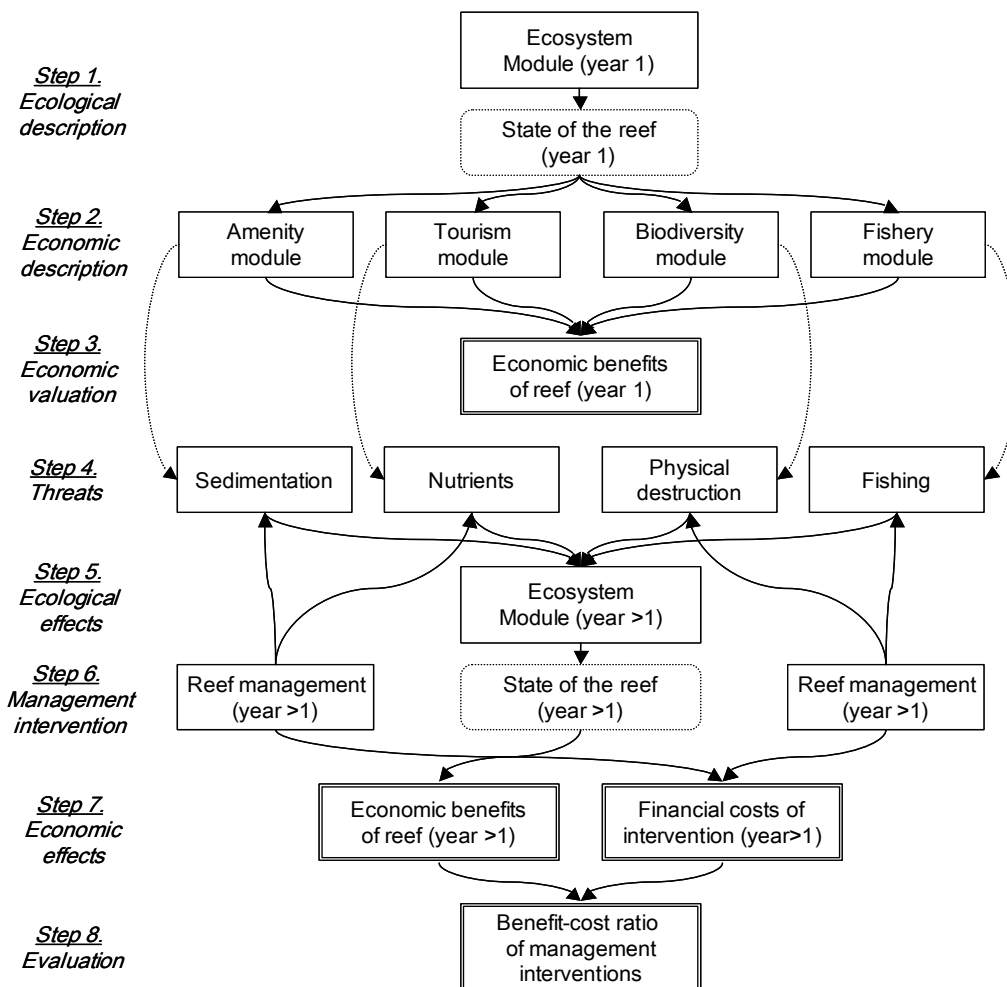
Figure E-2 General framework of the dynamic simulation model

Step 1 combines the 5 main ecological indicators (coral cover, coral biodiversity, fish stock, fish biodiversity and macro algae cover) into one composite "state of the reef" indicator. Step 2 of the model describes the various reef ecosystem functions, which are translated into reef-associated goods and services to Hawaiian society. *Goods* are renewable resources (fish, seaweed, etc.) and non-renewable resources (sand, etc. from mining of reefs.). The *services* of coral reefs include: (i) physical structure services, such as coastal protection; (ii) biotic services, both within ecosystems (e.g. habitat maintenance) and between ecosystems (e.g. biological support through mobile links);

(iii) information services (e.g. climate record); and (iv) social and cultural services, such as aesthetic values, recreation and gaming.

Each of these goods and services has associated economic benefits. The value of the sum of compatible uses of the above goods and services form the 'Total Economic Value' (TEV) of coral reef ecosystems (e.g. Spurgeon, 1992). This TEV can be calculated for a specific area or for alternative uses of that area (e.g. preservation, tourism, multiple use etc.). As shown in Figure E-3, the TEV of coral reef ecosystems can be subdivided into *use* and *non-use* values. Use values are benefits that arise from the actual use of the ecosystem, both directly and indirectly, such as fisheries, tourism and beach front property values. Non-use values include an existence value, which reflects the value of an ecosystem to humans, irrespective of whether it is used or not. Due to resource and budget constraints, we focused on the following goods and services: tourism, fisheries, coastal protection, amenity and property values, research and biodiversity, and cultural values. These values combine to give a 'lower boundary' estimate of the TEV:

Total Economic Value (TEV)

Use values   **Non-use values**

Direct use values	**Indirect use values**	**Bequest, option and existence values**
Outputs/services that can be consumed directly	*Functional benefits enjoyed indirectly*	*Functions that value either the future use, expected new information and based on moral convictions*
➤Extractive (capture fisheries, mariculture, aquarium trade, pharmaceutical)	➤Biological support to sea bird, turtle, fisheries ➤Physical protection to other coastal ecosystems, coastline, navigation)	➤ Endangered and charismatic species ➤ Threatened reef habitats ➤ Aesthetic reefscapes ➤ 'Way of life' linked to traditional use
➤Non-extractive (tourism/recreation, research/education, aesthetic)	➤Global life-support in terms of carbon storage	

Figure E-3: Subdivision of the total economic value of coral reefs.

The economic valuation of natural resources presents a major challenge: how to put a price-tag on goods and services from coral reefs that are not typically traded in the market. A host of valuation techniques are available to value these ecosystem goods and services. Those used in this study are the Effect on Production (EoP); Replacement Costs (RC); Damage Costs (DC); Travel Costs (TC); and the Contingent Valuation Method (CVM). EoP looks at the difference in output (production) as the basis of valuing reef services and is applied mainly to fisheries and the producer side of tourism in this study. RC can, for instance, be used for coastal protection estimates where data on investments in coastal erosion control are used as a proxy for the coastal protection service. DC uses the value of expected loss of the 'stock at risk' as a straightforward proxy for the value of the coastal protection service. TC is a revealed preference method, where travel time or travel costs are used as an indicator of the total 'entry fee', and therefore, a person's willingness to pay for visiting a Park. CVM tries to obtain information directly by posing

questions about willingness to pay for various environmental goods and services and/or willingness to accept their loss/degradation. Aggregating compatible benefits over time gives us the actual value of coral reefs.

These valuation techniques are used to monetize the various goods and services. Figure E-4 shows how these values translate into Total Economic Value, and highlight benefits of any management interventions. The benefits of interventions are the difference between the sum of reef-associated values from a 'management scenario' (or: 'with' case) and a 'business as usual scenario' ('without' case or baseline trend). These benefits can be compared to intervention costs through a cost benefit analysis of the management scenario. Discounted aggregation over time of these annual benefit streams gives the total economic value for a reef, according to a specific future course.
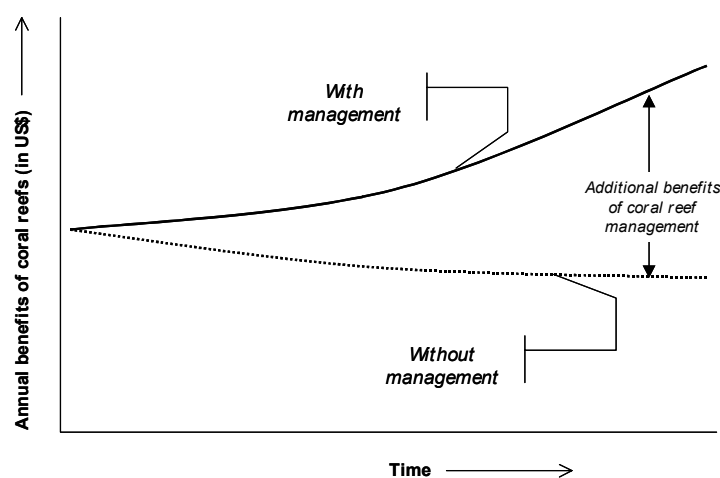
Figure E-4 Annual benefits of coral reefs with and without management

Data for the scenarios were obtained through dive shop surveys, surveys of real estate and the hotel/condo accommodations, a tourism and resident survey and an aquarium fisheries survey. In addition, data were obtained from various literature, government statistics and through benefit transfer. This latter technique uses data from comparable sites elsewhere as a form a proxy for an area for which no data are available.

Hanauma Bay is the remnant of the inside of a large volcano, whose crater partly collapsed into the sea. The Bay is located southeast of Waikiki on Oahu and is one of the most heavily used marine reserves in the world. The Hanauma Bay Marine Life Conservation District (MLCD), established in 1976, was the first MLCD in Hawaii. Reef monitoring by CRAMP showed an average coral cover of 25.8 percent at 3-meter depth and 27.0 percent at 10 meter depth. Macro-algae coverage was very low, at around 2 percent, while percentages of crustose coralline algae and turf algae were high. Fish were abundant, with densities of 417 fish per 125 m^2 at 3 m and 630 fish per 125 m^2 at 10 m.

In the late 1980s, Hanauma Bay was almost being 'visited to death' with 13,000 visitors a day at peak times. These crowds stirred up sediment, disturbed and trampled the coral and algae, dropped trash, fed the fish and left a slick of suntan lotion on the bay's surface. To decrease these impacts, the number of visitors was reduced by limiting the entry of cars to the parking lot. Also, a Hanauma Bay Educational Program (HBEP) was
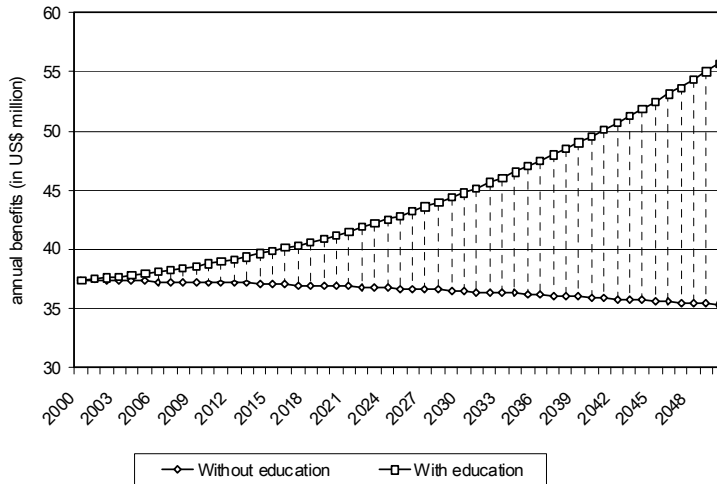
Figure E-5 Annual benefits 'with' and 'without' education center Bay

set up to improve the marine awareness of visitors. A $3 admission fee is charged to non-Hawaii residents over the age of 13, as well as a $1 parking charge per car. These fees, together with shop concessions, give Hanauma Bay a solid financial base.

In August 2002, a new visitor education center opened with an obligatory video to be watched by all visitors to the Bay. The investment costs of the new center were $13.5 million and operating expenses of the center are estimated at around $ 2 million annually. Is this a worthwhile investment? Our study showed that the overall net-benefits over time of the education program, in comparison to the absence of such a program, are roughly $100 million (net present value at 4% discount rate; Figure E-5). The costs of the program over time are estimated to be $29 million. This implies that, taking into account direct and indirect welfare effects, the program is completely economically justified.

The composition of the net benefits is as follows (Figure E-6): value of increased satisfaction of visitors to the bay (33%), an increase biodiversity value derived from a healthier coral reef (4%), and the so-called 'education spill-over effect' (63%). The latter comes from reduced coral trampling elsewhere by residents and tourists after watching the obligatory Hanauma video.

Our survey also showed that visitors are willing to pay more for their Hanauma Bay experience than the current $3 admission. Visitors spent an average of $38 per visit to
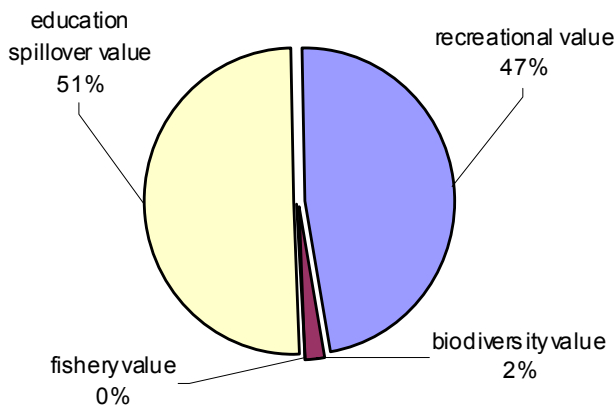
Figure E-6: Allocation of benefits of education program

the bay, of which the entry fee was only $3. About 85 percent of the respondents went snorkeling or diving. When queried about the value of their experience, only 13 percent felt they had spent too much; on average the respondents were willing to pay $5 more than they actually spent. In fact, visitors would be willing to pay an additional $8, if a significant share of that money was used for conservation purposes at Hanauma Bay.

Kihei's algae: Algae blooms have been a recurring problem on reef flats off the southern and western coasts of Maui for many years. This has caused significant, but localized, disturbance to the beach front, both in terms of its unattractive appearance and unpleasant odor. Potential contributing factors include wastewater discharge, leaching of injection wells, storm water and agricultural runoff, and golf course runoff. This leads to nutrient enrichment of the shallow reef area, which can cause phytoplankton blooms. These blooms limit the amount of sunlight reaching stony corals, thereby affecting their health. The major algal blooms occur in the North Kihei area, which has an algae cover of over 50 percent. Algae cover in South Kihei, which has not had such problems, is estimated at around 5 percent. The North Kihei algae problem is both a costly nuisance and a direct biological threat to local coral resources

Table E-2 Comparison of Sales Prices of 1 Bedroom Units in the Menehune Shores and the Royal Mauian Condominium Complexes for 1998-2000

Year	Menehune Shores		Royal Mauian		Difference
	# of Sales	Average price	# of Sales	Average price	% Difference in sales price
1998	6	156	3	440	182 %
1999	21	194	3	382	97 %
2000	12	222	8	495	123 %
Average 98-2000	194	190		439	131 %

Source: Hawaii State Tax Records

Currently, the largest economic cost is the drop in occupancy rates, room rates and property values in North Kihei. According to our survey, these declines can be largely attributed to the algal blooms. Table E-2 compares the sale prices of two apartment buildings, one in North Kihei (Menehune Shores) and one in South Kihei (Royal Mauian). These properties are largely identical in terms of architecture, design, and amenities. One- bedroom units in the 'algae zone' were, over the three year study period, only ~43% as valuable as one bedroom units in the 'non-algae zone'. Occupancy rates and room rates were also significantly different between the two zones.
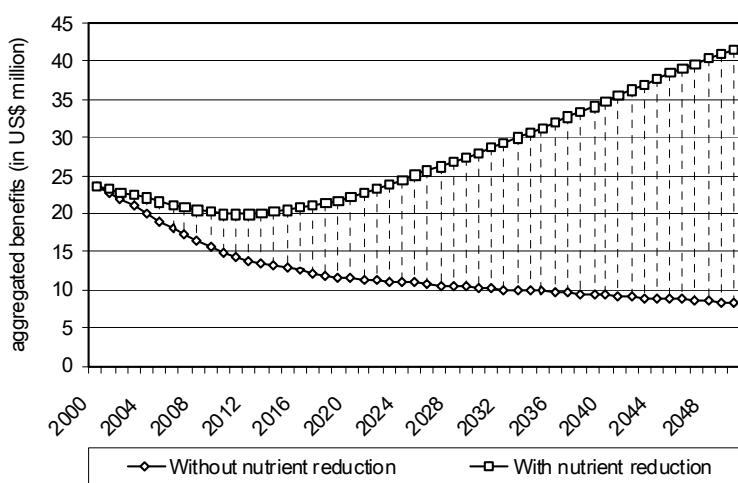

Figure E-7 Annual benefits 'with' and 'without' education center Bay

This case study estimated the net-benefits of solving the algal bloom problem in Kihei. Figure E-7 depicts the development of annual bene-fits derived from the coral reefs for two scenarios: one with and one without nutrient reduction. Not surprisingly, the annual benefits further decline from $25 million to $9 million

if the coral reef gradually disappears and algae blooms continue to occur. However, in a situation where nutrients are successfully reduced,, the annual benefits will eventually increase by almost $30 million. The majority of this increase can be attributed to the growth in property values. In addition, recreational values, in terms of snorkeling and diving, increase over time by about $2 million. Figure E-8 shows the allocation of these benefits.

It is not clear how the algae blooms can be eliminated. However, the associated economic benefits of their elimination are such that major spending is justified. For instance, upgrading the sewerage plant is estimated to cost $ 13 million in capital investments and $ 0.5 million per year in operating costs. These costs fall well within the economically justifiable 'spending envelope', if leaching from injection wells turns out to be a major contributor to the algae blooms. Note that several important

Figure E-8: Allocation of benefits of elimination of the algae problem

additional benefits, such as reductions in health risks and water savings, have been excluded from the study. Therefore, even larger expenditures on sewerage and run-off reductions would certainly be a worthwhile investment; they would benefit both the economy and the marine environment.

Aquarium fisheries along the Kona coast: The aquarium fish industry, though relatively small, is one of the largest inshore fisheries in the State of Hawaii. Its gross sales amount to $3.2 million, with industry profits of $1.2 million. Following spectacular growth in the 1980s, these values have been reasonably stable over the last decade. The figures are based on our own research and are considerably higher than official Department of Aquatic Resources (DAR) statistics. The largest share of the aquarium fish collection, 58% of the State total, takes place along the West Hawaiian coast (Kona coast). In 2002, the estimated gross value and profits for the 22 collectors and 8 wholesalers were US$ 1.8 million and US$ 0.7 million respectively (Table E-3). Of the total catch, 90% is exported out of State. The Yellow Tang (lau´ipala) fish is the 'bread-and-butter' of the aquarium trade, making up 78 percent of total catch. The other 3 main ornamental fish are: Goldring Surgeonfish (kole); Achilles Tang (paku'iku´i) and Naso Tang (umaumalei). In terms of value, these four species together contribute 87.2 percent to the total. Catch per hour of effort has gone up dramatically over the last decade, from less than 10 fish per hour in 1990, to over 60 in1999. This collection rate is higher than in Australia.

Table E-3   Estimated Gross value and profits of the West Hawaii aquarium fisheries

Industry Segment	Gross value	Profit
Independent contractors	$ 633,000	$ 380,000
Wholesalers	$1,209,000	$ 302,000
Total	$1,842,000	$ 682,000

Source: own calculations (by Jan Dierking)

In 2000, 35% of the Kona coast became designated as a Fish Replenishment Areas (FRAs), in which aquarium fish collection is not allowed. This designation was largely due to public concern that aquarium fish populations were declining. Since then, tensions have subsided and the public accepts present catch effort. The FRAs have limited potential catch areas, but preliminary findings suggest that unprotected areas are now more heavily fished than before. It is important to understand that the current situation is transient. Biologists hope that FRAs will eventually benefit the aquarium fishery, through enhanced recruitment and possibly spill-over. This should then counterbalance higher collection intensities in other areas. Already, biodiversity has increased in the FRAs. This is also beneficial for the recreation industry (snorkelers; divers).

In terms of economic value, the aquarium fishery along the Kona coast remains small in comparison with other economic activities and in terms of its contribution to local welfare. The inhabitants of the Kona coast have a strong attachment to marine life; it is calculated that this is worth around $1.2 million in local snorkel/dive trips, as well as in terms of the non-use value they attribute to coral reefs. In addition, around $7.1 million of tourist expenditure can be attributed to the reefs along the Kona coast. In total, the reef-associated benefits along the Kona coast are around $ 17.7 million. The composition of this total benefit is given in Figure E-9. It remains to be seen whether the FRAs will benefit the aquarium fishermen in the long run. However, at least the FRAs seem to benefit the local population and the tourism industry.

Figure E-9 Composition of reef-related benefits in Kona

Total Economic Value of reefs for the Main Hawaiian Islands: The outlined case studies, together with general data on fisheries, recreation, property value, and biodiversity, allow us to come up with a 'lower bound' estimate for the Total Economic Value of reefs for the Main Hawaiian Islands. It is assumed that benefits remain constant over time. The time period considered is 50 years and results are presented at a discount rate of 3 percent. Table E-4 shows the composition of the main economic benefits of the coral reefs in Hawaii, as well as the benefits for each of the case study sites. The average annual benefits accruing from the Hawaiian coral reefs amount to $385 million. This leads to a net present value of nearly $10 billion (at a discount rate of 3%). This figure represents the asset value of the coral reefs of the Main Hawaiian Islands. Sensitivity estimates suggest that without discounting, this asset value would be as much as $19 billion, while a discount rate of 15% would produce a corresponding net present value of $2.8 billion.

The largest contribution (85%) to the yearly benefits of $364 million is the annual value added by recreation and tourism ($304 million). Second is the amenity/property value, with benefits of $40 million per annum. The impact of reefs on the total property value in Hawaii is modest, but as total property values are so high in Hawaii, a high coral reef

related value is still generated. The third most important benefit is biodiversity. This is partly expressed in terms of reef-related research expenditures ($10 million per year) and partly in terms of non-use value ($7 million per year). The latter value was estimated through benefit transfer. A new study by NOAA will substantiate this value. Note that reef-related fisheries are the least important in economic terms, with an annual added value of $2.5 million per year.

Table E-4   Annual benefits and the net present value of the Hawaiian coral reefs and the different study sites

Benefits		Hanauma Bay, Oahu	Kihei Coast, Maui	Kona Coast, Hawaii	Hawaii - overall
Recreation/Tourism	*Million$/year*	36.23	8.02	8.06	304.16
Amenity/Property	*Million$/year*	0.00	18.26	4.57	40.05
Biodiversity	*Million$/year*	1.11	1.71	4.35	17.00
Fisheries	*Million$/year*	0.01	0.10	0.70	2.50
Education spill-over	*Million$/year*	0.22	-	-	-
Total annual benefits	*Million$/year*	37.57	28.09	17.68	363.71
Net Present Value @ 3%	*Million$*	1,053	522	389	9,722

Table E-4 also shows the various benefits for the three case studies, as well as the figures for the State of Hawaii. For Hawaii overall, the asset value of its coral reefs are estimated to be worth $ 9,7 billion. This is the determined as the sum of all future quantified benefits streams over a 50-year period and a 3% discount rate. Regarding the individual sites, the differences are quite surprising. First of all, reefs at Hanauma Bay have a higher asset value (over $ 1 billion) than the whole Kona coast (less than $ 400 million). Also, benefits related to reef-associated amenity/property value dominate in Kihei, while tourism/recreation constitutes over 95% of benefits in Hanauma Bay.

The annual benefits and total economic values can also be expressed on a 'per area' basis. Table E-5 shows these values for each of the three case study sites. This enables a comparison between the three case studies in economic value per acre. Not surprisingly, Hanauma Bay is the most valuable site in terms of coral reefs, in Hawaii and perhaps even in the world. This is due to high intensity recreational use in what is a very confined area. Reefs at Hanauma are ecologically average for Hawaiian standards, yet are more than 125 times more valuable than the more ecologically diverse reefs at the Kona Coast. This demonstrates that economic values can differ dramatically from ecological values or researchers' preferences.

Table E-5   Annual benefits and net present values of the different case study sites per area of coral reef

		Hanauma Bay, Oahu	Kihei Coast, Maui	Kona Coast, Hawaii
Total annual benefits	*$/m²*	91.63	3.51	0.73
Net Present Value	*$/m²*	2,568	65	19
Total annual benefits	*$/acre*	370,819	14,210	2,944
Net Present Value	*$/acre*	10,393,033	264,231	78,698

For natural resource damage assessment in reef areas, the economic valuation of coral reefs is a first step to determine losses. Damage claims basically have two main components: (i) the cost of restoring the damaged resource to its original state; and (ii) the compensation of interim losses from the time of damage until full recovery. Figure E-10 shows both the restoration costs as well as the interim costs (referred to as unavoidable natural resource losses). In the absence of intervention, natural recovery could take place in this hypothetical case but complete recovery would take much longer. The additional foregone natural resource benefits in this case are referred to as the 'avoidable natural resource losses'. Unless the restoration costs are exorbitant, damage claims based on the sum of restoration costs and compensation of interim losses are both economically justified and fair. The interim losses need to be assessed on a case-by-case basis and depend on the extent of damage incurred by the goods and services that a coral reef ecosystem provides at that specific site. It will in any case be lower than the Total Economic Value of the area affected. Restoration costs vary also considerably. Cases in Florida show that these can range from $550 to over $10,000 per square meter.

Both the unavoidable and avoidable natural resource losses are difficult to assess. This is true both for the ecological and the economic assessment. There can be major uncertainties with respect to possible ecological phase shifts with enormous implications for property values of adjacent coastal areas. In this case, even rather high restoration costs seem economically justified. Whether court settlements from damage claims should actually be used for restoration or rather for more general coastal zone management is an open question.
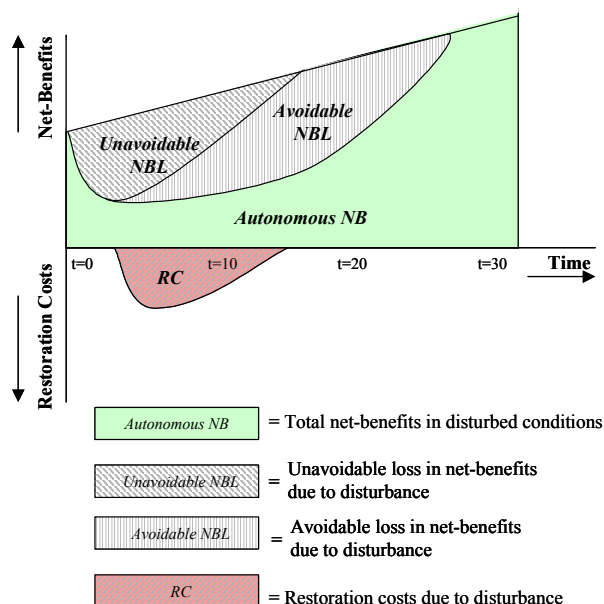
Figure E-10 Illustration of damage assessment

1. Introduction

Coral reefs and their associated marine life are one of the greatest natural treasures in the world. The State of Hawaii is well exceptionally well endowed with 410,000 acres of coral reef, hosting over 5,000 known species of marine plants and animals. Also, approximately 85% of all U.S. coral reef areas occur within the Hawaiian Archipelago (Gulko et al., 2002). Coral reefs form the core of the livelihood for many of Hawaii's people, through tourism and fisheries. Reefs also provide a natural barrier against wave erosion and coastal hazards, thereby protecting coastal infrastructure, tourism beaches and human life. In addition, because of their unique biodiversity, they are of great interest to scientists, students, pharmaceutical companies, and others. Also, coral reefs play an important spiritual, and cultural role. These and many other functions give coral reefs a crucial and growing value in Hawaii.

Despite this, the quality of coral reefs in Hawaii is declining even at more remote reefs. A variety of anthropogenic practices threatens reef health and therefore jeopardizes the benefits flowing from these services and goods. These threats include mainly local issues, such as overfishing, excess nutrients, invasive algae, sedimentation, and tourism pressure impacts. These threats are the result of a combination of factors, such as market failures, undervalued resources, lack of enforcement and lack of awareness. Sadly, the traditional *Ahupua'a* concept, which used to help ensure that impacts of land-based activities in Hawaii on coral reefs were taken into account, has been eroded by modern state-level planning and the cash-economy.

Economic valuation can highlight the idea to Hawaii's people that everything in nature hangs together by showing the costs of neglecting this dependency and by illustrating the importance of reef services in monetary terms. It can thereby play a potentially crucial role in communicating the importance of reefs to Hawaii's people and policy makers. In addition, economic valuation can play an important role in damage assessment in case of oil spills, ship groundings, sediment dumping, etc. Finally, it can help justify on economic grounds financial commitments by the State and Federal government in coral reef management.

The objective of the study is threefold: *(i) to assess the economic value of selected coral reef areas in Hawaii and of Hawaii as a whole, (ii) to determine the economic costs of reef degradation; (iii) to compare the costs of benefits of management options to reverse these trends.*

As shown in Figure 1.1, the following four steps were followed in this project. In phase 1, numerous interviews were conducted with stakeholders in the research and policy community to get a better understanding of the context of coral reefs in Hawaii.[1] Also, the sites for the case studies were selected. In phase 2, the data required for the analysis were collected. In phase 3, a generic conceptual model was developed to address the

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[1] Two types of consultation have been used. First, a workshop was held on 25 October 2001 by the Hawaii Coral Reef Initiative (HCRI) Research Program addressing the most important threats to Hawaiian reefs. Second, individual interviews were held by the authors with coral reef experts in Hawaii (see attached list in the Annex).

complex relationships within and between the coral reef ecosystem and the economy. Also, the separate case studies selected in phase 1 were conducted to determine the specific economic benefits of coral reef ecosystems. These case studies also addressed possible management options to respond to the threats in the respective case studies. The results of the three case studies were subsequently extrapolated to a Hawaiian-wide analysis, determining the overall value of the coral reef of the Main Hawaiian Islands of Hawaii. In the final stage of the project, phase 4, the report was put together and presentations were held for the research and policy community.

Phase 1: Inception
Inventory of case studies and research/policy network

Phase 2: Data collection
Ecosystem, threats, benefits, and interventions

Phase 3: Modeling & Results
Case studies, and extrapolation to Hawai'i

Phase 4: Dissemination
Report writing, presentations, and follow-up
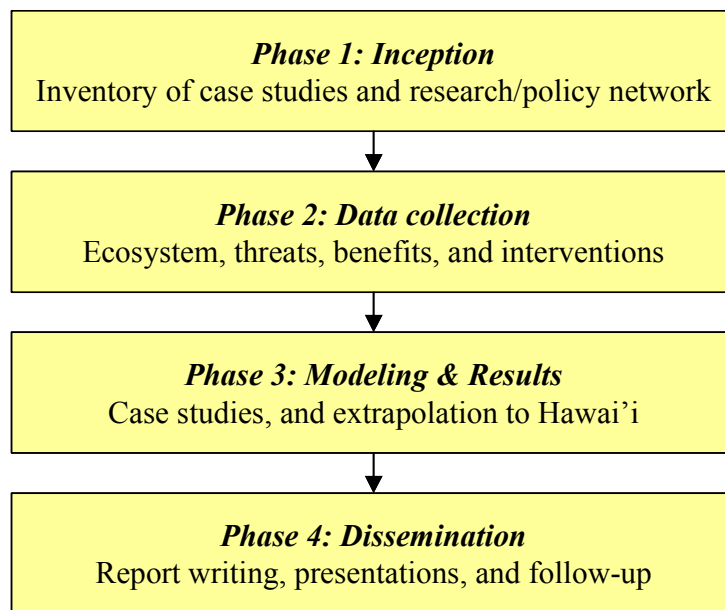
Figure 1.1   Overall project approach of the economic valuation of coral reefs

This final report aims at providing an overview of the approach and findings of the project. The structure is as follows. In Chapter 2, a description of the coral reefs in Hawaii is given together with their benefits and threats. Specifically, three major threats (i.e. excess nutrients / algae / coastal hardening, tourist pressure and overfishing) are outlined and management options are discussed. Chapter 3 presents an overall methodology of quantification and valuation of the costs and benefits. Chapter 4 discusses the ecological-economic model that forms the basis of the interaction between the natural world and the economy. Chapters 5, 6 and 7 present the three case studies (Hanauma Bay – Oahu; Kihei – Maui and Kona coast – Big Island). In Chapter 8, these case studies are combined to give an overall economic valuation for the State of Hawaii (main islands). Chapter 9 gives recommendations, some caveats and ideas for future work. The appendices provide background materials for each of the threats and presents the surveys and their results.

2. Coral reefs in Hawaii: status, sites and threats

This chapter gives a background of the status of coral reefs in Hawaii, as well as the threats and possible interventions. The discussion of the status of Hawaian coral reefs provides the basis for the selection of the case studies (this chapter) and for the model inputs (Chapter 4).

2.1 Status of Coral Reefs in Hawaii[2]

There are four types of coral reef ecosystems across the State of Hawaii: fringing reefs, barrier reefs, atolls and reef communities.

- *Fringing reefs* are coral reefs growing in shallow waters and bordering the coast closely or separated from it by a narrow stretch of water. Fringing reefs consist of several zones that are characterized by their depth, the structure of the reef, and its plant and animal communities. These regions include the reef crest, the fore reef, and the spur and groove or buttress zone (the region of coral growth which includes rows of corals with sandy canyons or passages between each row). Fringing reefs occur in many areas in Oahu, Maui, Moloka'i and elsewhere in the State of Hawaii.

- *Barrier reefs* are reefs that are separated from land by a lagoon. These reefs grow parallel to the coast and are large and continuous. Barrier reefs also include regions of coral formation that include the zones found in fringing reefs along with patch reefs, back reefs, as well as bank reefs. Kaneohe Bay on Oahu is the only barrier reef in the State of Hawaii.

- The third type of coral reefs are *atolls*. Atolls are annular reefs that develop at or near the surface of the sea when islands that are surrounded by reefs subside. Atolls separate a central lagoon and are circular or sub-circular. There are two types of atolls: deep sea atolls that rise from deep sea and those found on the continental shelf. Some Northwest Hawaiian islands are atolls, such as Kure atoll and Midway atoll.

- *Reef Communities* are shallow benthic coral reef structures, for instance on lava rock. These do not form large reef crests and are pockets of corals and small reef structures in areas dominated by other benthic forms. The reefs along Kona coast on Big Island are examples of reef communities.

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[2] Important literature available on coral reef ecosystems in Hawaii include among others: A.M. Clark and D.A. Gulko (1999) *Hawaii's State of the reefs report*, Department of Land and Natural Resources, Honolulu, Hawaii. p.41. & Gulko, D.A., J.E. Maragos, A.M. Friedlander, C.L. Hunter and R.E. Brainard (2001) *The status of coral reefs in the Hawaiian Archipelo.* Department of Land and Natural Resources, Honolulu, Hawaii. p.69. Most of the data in this section are from the latter report.

The coral reef areas of the Hawaiian Islands comprise almost 85% of all coral reef area under the U.S. jurisdiction. The Hawaiian territory is divided into the Main Hawaiian Islands and the Northwest Hawaiian Islands (see Table 2.1).

Table 2.1   Summary on data of the Main Hawaiian Islands

	Land area (km^2)	Reef area (km^2) [0-3 naut.miles]	Reef area (km^2) [3-200 naut.miles]
Main Hawaiian Islands			
- Hawaii	10,433.1	252	0
- Maui	1,883.7	270	0
- Kaho'olawe	115.5	58	0
- Molokini	0.1	1	0
- Lanai	364	95	0
- Moloka'i	673.5	128	870
- O'ahu	1,546.5	504	0
- Kauai	1,430.5	266	0
- Ni'ihau	179.9	64	0
- Kaula	0.6	18	10
Total	*16,627.4*	*1,656*	*880*
Northwest Hawaiian Islands			
- Nihoa	0.7	20	226
- Necker	0.7	98	1,440
- French Frigate Shoals	0.7	456	277
- Gardner Pinnacles	0.02	86	1,818
- Maro	-	18	1,490
- Laysan	4.1	34	23
- Lisianski	1.5	202	777
- Pearl & Hermes	0.3	1,166	0
- Midway	6.4	203	20
- Kure	1	147	20
Total	*15.4*	*2,430*	*6,091*

Source: Gulko et al. (2002)

The majority of the coral reef area is located in the Northwest Hawaiian Islands (8,521 km^2). Although the coral reef area in the Main Hawaiian Islands is smaller (2,536 km^2), its economic importance outweighs that of the Northwest Hawaiian Islands. For example, the annual number of visitors on the Main Islands is 11 million while the Northwest Island receive only 5000 visitors per year. Given this significant contrast in characteristics and the large difference in data availability, the present study will confine itself to the Main Hawaiian Islands.

There are approximately 60 named species of stony corals in the Hawaiian Archipelago (Maragos *et al.* in prep.) with an endemism of around 25%. Live coral cover in the Main Hawaiian islands is around 18% on average for all sites surveyed under the Hawaii Coral Reef Assessment and Monitoring Program (CRAMP). In addition, there are thought to be over 400 species of marine algae. There are 557 species of reef and shore fishes in Hawaii, 100 species of sponges, 1071 species of mollusks, 884 species of crustaceans and 278 species of echinoderms (all data from Gulko et al. (2000); for references, see therein).

2.2 Site Selection

The ecological characteristics of the coral reef do not have a major impact on its economic value. Divers and snorkelers do not have any strong preference for fringing over barrier reefs, for instance. Other functions may also have rather similar economic benefits. Only in terms of coastal protection functions does reef value vary more widely. Reef communities do not really have this coastal protection function. Therefore, rather than making a subdivision according to ecological habitats, we distinguish reefs in terms of social-economic variations. This will be explained in the next section.

Three case studies have been selected within the region of the Main Hawaiian Islands. Criteria that have been used for the selection are both practical and more economic. Practical criteria include the location (i.e. even distribution among the islands), the reef type (i.e. variation of ecosystems), type of threats (i.e. variation of threats addressed; see the Section below), data availability (i.e. how is the data access), and representativeness (i.e. can the case studies be used for extrapolation Hawaiian-wide). Economic criteria refer to whether the case studies address a range of benefits such as snorkeling, diving, fisheries, coastal protection, ornamental fish harvesting and biodiversity.

As indicated on the map in Figure 2.1, the following sites have been selected:

4. Hanauma Bay (O'ahu) addressing tourist overuse;
5. Kihei and Ka'anapali (Maui) addressing excessive nutrients and algae blooms;
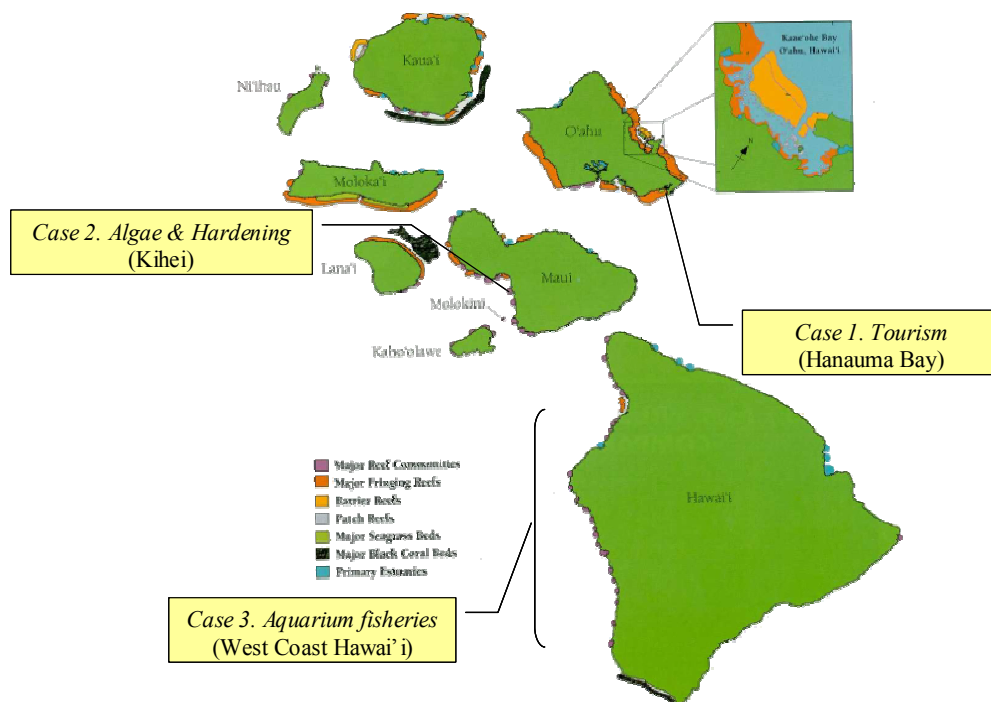6. Kona coast (Hawai'i) addressing overfishing;

Figure 2.1   Map of the Main Hawaiian islands and the selected case studies

2.3 Threats

The quality of coral reefs in Hawaii is declining. Most of the causes of this decline are thought to be of anthropogenic origin. The threats in Hawaii have mainly local causes, such as excess nutrients, sedimentation, overfishing and tourism-overuse. Global issues such as climate change are expected to be of less importance to Hawaiian coral reefs.[3] We will focus on three key human-induced threats:

- *Overfishing*: Though not necessarily as destructive as other threats, overfishing does damage coral reefs, mainly through a reduction in fish diversity. Selective fishing can also take away algae-eaters, thereby changing the space-competitive equilibrium between corals and algae. Overfishing also decreases the value to recreational divers, who are eager to see both large predators and an abundance of small colorful fish. In Hawaii, the result of overfishing in the nearshore areas of the Main Hawaiian islands (MHI) is particularly visible when compared to the Northwest Hawaiian islands (NWHI). For instance, the gross mean standing stock of fish is more than 260% greater in NWHI than in MHI (Friedlander and de Martini, 2002). In this report, we will mainly focus on overfishing with regards to the case study on aquarium fisheries along the Kona coast.

- *Excess nutrients, run-off and coastal hardening*: Coastal development can lead to severe damage for coral reefs. Insufficient sewage treatment can lead to excess nutrients which stimulates algae growth, which can overgrow the corals. Sedimentation, both from urban areas and from agriculture, smothers corals as it prevents the symbiotic algae from capturing sunlight. These problems are particularly acute close to estuaries of rivers and urban centers (Rogers, 1990). The case study in Kihei in this report will focus on the combination of excess nutrients, run-off and coastal hardening, thought to be some of the main causes of the algae blooms in North Kihei.

- *Tourism over-use*: Although tourism can be a good way to generate income from coral reefs, it can also be a threat to the reefs. In this sense, tourism is a two-edged sword. Uncontrolled tourist development can lead to sewage problems, sedimentation, as well as physical destruction of coral through trampling, contact with divers and anchor damage. In the Hanauma Bay case study, we will specifically look at the income generated from tourism and at the threat of tourism over-use.

2.4 Interventions

To respond to the above-mentioned threats, several management alternatives can be identified. These are, for example, the establishment of marine parks in Hawaii to prevent overfishing and the improvement of sewerage and runoff management to avoid algae blooms. Such management alternatives will be compared with the baseline to obtain estimates of the difference in 'with' and 'without' scenarios. This analysis may result in specific recommendations aimed at areas in which resource enhancement activities are considered.

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[3]   Due to Hawaii's geographical position, temperature changes due to climate change are limited. Also, effects from El Nino have so far been limited (Hannah Bernard, pers. comm.).

For each of the threats covered in the case studies, interventions will be discussed later in the report.

- For policies directed at *tourist overuse*, specific attention will be given to increasing the environmental awareness of the visitors. This plays specifically in the Hanauma Bay case study. A visitor center open in August 2002 at Hanauma Bay which included a compulsory educational tour by the visitors.

- To address the *excess nutrients, run-off and coastal hardening problem*, land-based policies such as the improvement of sewage treatment, modification of pesticide and fertilizer use in agriculture and on golf-courses, etc, are investigated. A combination of measures is proposed for the North-Kihei case study where the problems with algae are particularly severe and where major efforts are underway to clean up the beach.

- With regard to *overfishing*, different fishery management measures are possible, from no-take zones to closed seasons. We have focused on the fish replenishment areas which were established along 30% of the nearshore area of Kona coast in 2000. This forms the basis for our Kona case study.

3. Methodology

The coral reefs of Hawaii are subject to mutual relationships between ecology and the economy. The complexity of these relationships is substantial. To capture these complexities, the study follows an interdisciplinary approach.[4] This chapter discusses the overall approach and the specific economic methods applied in this project. For instance, the goods and services as well as economic benefits of Hawaiian coral reefs and the methods to assess these benefits are elaborated on. Cost benefit analysis to compare benefits and costs of interventions will also discussed. The next chapter will focus on the ecological part of the model and the interactions with the economic parameters.

3.1 Overall approach

The basis for the analysis is an integrated model that links ecology and economy in a dynamic manner. Figure 3.1 provides an overview of the approach of the study. The figure shows how the mutual relationships in the model evolve. On the one hand, it shows how the coral reef ecosystem generates a wide range of goods and services for the Hawaiian society (see Section 3.2 below). Benefits are derived from these goods and services (Section 3.3). These benefits can be measured by applying a range of valuation techniques (Section 3.4). On the other hand, the over-exploitation of these economic goods and services can lead to threats to the coral reef ecosystems and can destroy the flow of goods/services. The measurement of the impact of these threats requires more technical approaches such as dose-response functions and hydrological models. Management options lead to benefits (reduction of threat) and typically cost money. Therefore the final step in the analysis is to compare these costs and benefits (Section 3.7).

For a transparent overview of the economic value of the coral reefs of the State of Hawaii, project boundaries need to be clearly defined. The two main boundary definitions are:

- The *temporal* boundary of the project is set for the period 2000 to 2025. This period leaves enough time for the main ecological effects to come into effect, while it is short enough to still be able to make some prediction about future developments.
- The *geographic* boundaries are the boundaries of the study area and the impact area. Tourists can go diving in the study area while staying and spending most of their money outside this area[5]. Three sites have been selected (see Chapter 2 above), each with various coral reef characteristics, and varying in degree and type of economic activity and reef use and threat.

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[4]   A computer model will be developed to capture these complexities. The model will be developed with the software VENSIM, which is especially designed to simulate complex processes over time.

[5]   The Northwestern Hawaiian Islands will be excluded from the study, due to their distinct socio-economic characteristics and the lack of available data
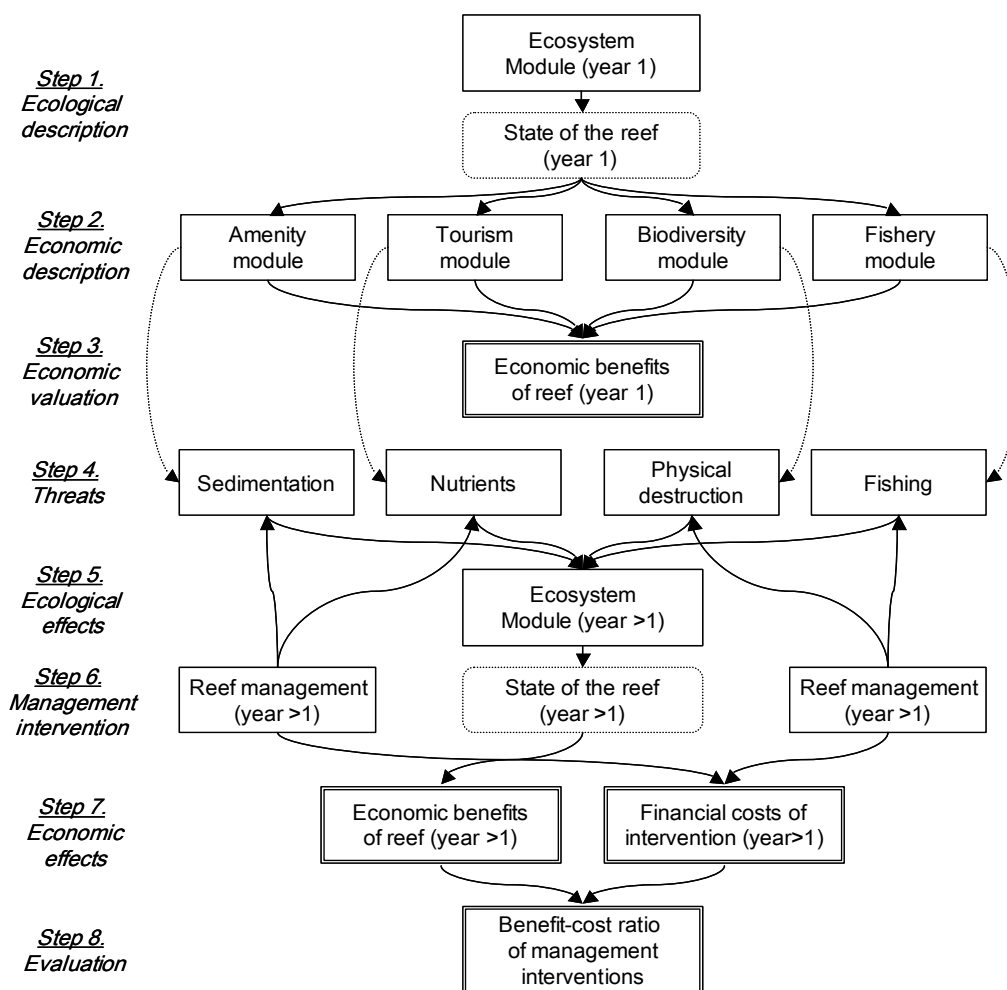
Figure 3.1   General framework of the dynamic simulation model

3.2 Coral reef functions, goods and services

Figure 1.1 above shows the interactions between the ecology and the economy. At the core of these interactions are the coral reefs, providing various ecosystem functions which translate into reef-associated goods and services to Hawaiian society. Each of these goods and services has associated economic benefits. *Goods* of coral reefs in general are sub-divided into renewable resources (fish, seaweed, etc.) and non-renewable goods such as mining of reefs (sand, etc.). In other areas in the world, coral mining for lime and building materials is also practiced, but this does not occur any more in Hawaii. The *services* of coral reefs in general are categorized into: (i) physical structure services, such as coastal protection; (ii) biotic services, both within ecosystems (e.g. habitat maintenance) and between ecosystems (e.g. biological support through mobile links); (iii) bio-geo-chemical services, such as nitrogen fixation; (iv) information services (e.g. climate record); and (v) social and cultural services, such as aesthetic values, recreation and gaming.

Table 3.1   Goods and l services of coral reef ecosystems

Service	Products
Goods	
Renewable resources	Sea food products, raw materials and medicines, other raw materials (e.g. seaweed), curio and jewelry, live fish and coral collected for aquarium trade
Mining of reefs	Sand for buildings and roads
Services	
Physical structure services	Shoreline protection, build-up of land, promoting growth of mangroves and seagrass beds, generation of coral sand
Biotic services (within ecosystem)	Maintenance of habitats, biodiversity and a genetic library, regulation of ecosystem processes and functions, biological maintenance of resilience
Biotic services (between ecosystems)	Biological support through 'mobile links', export organic production etc. to pelagic food webs
Bio-geo-chemical services	Nitrogen fixation, CO_2 / Ca budget control, waste assimilation
Information services	Monitoring and pollution record, climate control
Social and cultural services (including tourism)	Support recreation, tourism, aesthetic values and artistic inspiration, sustaining the livelihood of communities support of cultural, religious and spiritual values

Source: adapted from Moberg & Folke (1999)

3.3 Economic Benefits of Coral Reefs

The goods and services discussed above have associated economic values. The value of the sum of compatible uses of the above goods and services form together the Total Economic Value (TEV) of coral reef ecosystems (e.g. Spurgeon, 1992). This TEV can be calculated for a specific area or for alternative uses (e.g. preservation area, tourism area, multiple use area, etc.). One purpose of calculating the TEV of coral reefs and carrying out a Cost-Benefit Analysis (CBA) is to obtain data for informed policy discussions. Examples are stakeholder discussions regarding the societal costs of on-going reef-destructive activities and government discussions regarding the economic rationale and budget allocation for marine park management. Another purpose for calculating the TEV is to assess the damage costs of disasters such as oil spills or ship groundings.

As shown in Figure 3.2, the TEV of coral reef ecosystems can be subdivided into *use* and *non-use* values. Use values are benefits that arise from the actual use of the ecosystem, both directly and indirectly. Direct use values come from both extractive uses (fisheries, pharmaceuticals, etc.) and non-extractive uses (tourism). Indirect use values are, for example, the biological support in the form of nutrients. Another example is the value from coastal protection that coral reefs provide. Non-use values consist of option, bequest and existence values. The concept of option value can be seen as the value now of potential future direct and indirect uses of the coral reef ecosystem. An example is the potential of deriving a cure for cancer from biological substances found on reefs. Bio-prospecting is a way of deriving money from this option value. Related to the option value is the so-called quasi-option value, capturing the fact that avoiding irreversible destruction of a potential future use gives value today. The bequest value is related to

preserving the natural heritage for generations to come. The large donations that are given to environmental NGOs in wills are an example of the importance of the bequest concept. The existence value reflects the idea that there is a value of an ecosystem to humans irrespective of whether it is used or not.
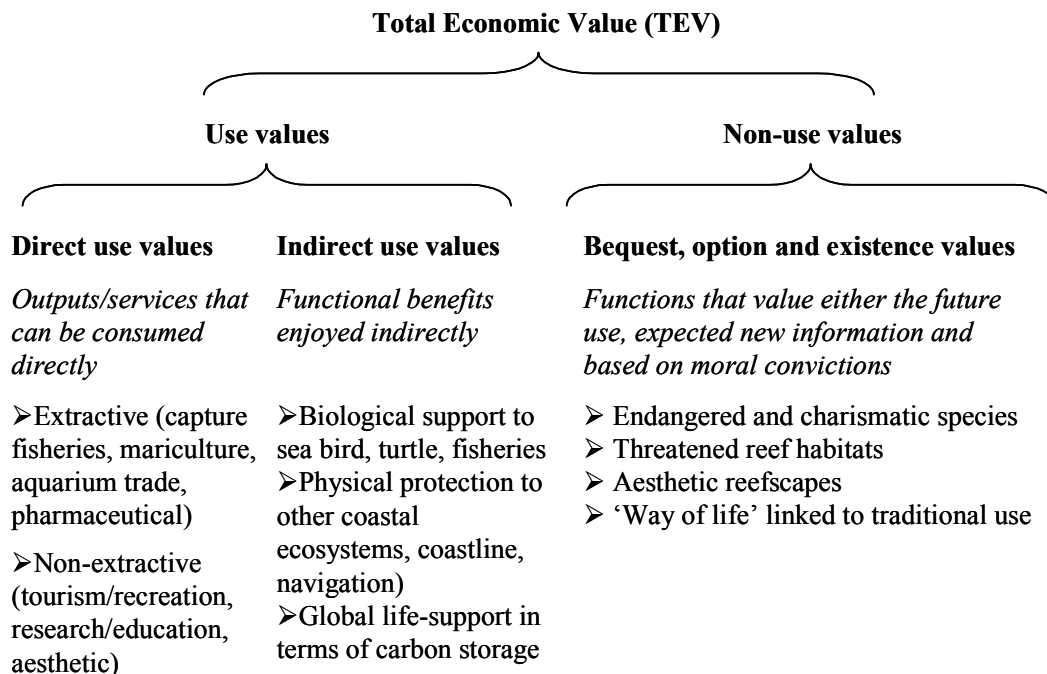
Total Economic Value (TEV)

Use values   **Non-use values**

Direct use values	**Indirect use values**	**Bequest, option and existence values**
Outputs/services that can be consumed directly	*Functional benefits enjoyed indirectly*	*Functions that value either the future use, expected new information and based on moral convictions*
➤Extractive (capture fisheries, mariculture, aquarium trade, pharmaceutical) ➤Non-extractive (tourism/recreation, research/education, aesthetic)	➤Biological support to sea bird, turtle, fisheries ➤Physical protection to other coastal ecosystems, coastline, navigation) ➤Global life-support in terms of carbon storage	➤ Endangered and charismatic species ➤ Threatened reef habitats ➤ Aesthetic reefscapes ➤ 'Way of life' linked to traditional use

Figure 3.2   Subdivision of the total economic value of coral reefs

Resource and budget constraints call for a selection of the most important goods and services for coral reef valuation. Additionally, the natural science basis for quantification of biotic and bio-geo-chemical services is controversial. Therefore, the following goods and services will be quantified to obtain a 'lower boundary' estimate of the TEV:

- *Tourism*: Tourism is big business in Hawaii. Though not all tourism depends on coral reefs, much coastal tourism depends to an extent on the quality of the reefs. The tourism function of coral reefs depends crucially on the location. Accessibility is one of the most important determinants of tourism potential. The recreational use of coral reefs relies both residents and tourists. Native Hawaiians do have a special feeling for the sea, but actually are only rarely divers. They more often are subsistence and recreational fishermen. This is another important use, but different from that captured at the popular dive and snorkeling spots. For the economic valuation, sites will be selected that vary in their accessibility and which can be distinguished in areas with major tourism (potential) and areas without this potential. Note, however, that tourism can also be a threat, due to solid and human wastes, uncontrolled development, boat anchoring and coral breaking (inexperienced divers). For a study on tourism carrying capacity, see Dixon et al. (1995). For a summary of literature on tourism-related damage, see Cesar (2000).

- *Fisheries*: Both commercial, subsistence and recreational fishing is important for the Hawaiian economy. Commercial fisheries focuses both on pelagics and on reef fisheries. Russ (1991) summarizes 18 studies on yields of small coral reefs in South East Asia and the Pacific, with estimates ranging from 0.42 to 36.9 metric tons per

km2 per year. According to Russ (1991), these differences may be due to a variety of factors, including: (i) the size difference of reefs; (ii) the level of effort; (iii) the definition of the total reef area; and (iv) the definition of reef fish. The reef fishery yields in Hawai'i are much lower than the average in the Russ' study, due to their specific conditions (Grigg, 1994 and references therein). Also important is recreational fisheries, mainly in deeper waters but also in reef areas. Surveys in the Florida Keys and The Great Barrier Reef (Australia) reveal the growing importance of recreational fisheries for local economies. [6]

- *Aquarium and curio trade*: Hawaii is famous for its black and gold corals. It is also one of the most important centers of the global aquarium fish trade. Part of the aquarium and curio trade depends on collection from Hawaii, while the rest is trans-shipment. For our study, the former is of particular importance and will be quantified under the project.[7]

- *Coastal Protection*: Coral reefs act as wave breakers and thereby fulfill an essential function in coastal protection. The valuation of the impact of decreased protection due to a variety of threats depends on current and/or potential future economic activities of the area. Data from the Caribbean reveal a loss of 0.2 m/yr (Cambers 1992), while others report much larger losses of coastline (Berg et al. 1999). Often, hotel operators and government agencies spend significant amounts of money on shoreline protection in areas where reef degradation has led to erosion (Ohman and Cesar, 2000). However, most reefs in Hawaii play this coastal protection function to a much lesser extent than in some other parts of the world. For instance, along Kona coast, the reef communities probably play a negligible role. Along the West coast of Oahu, on the other hand, the reef crest plays an important role but this does not seem to depend on live coral. Therefore, we have not incorporated the coastal protection function in our valuation estimate.

- *Amenity value and property value:* The beautiful view from beach front properties with the different shades of blue and green suggest that part of the amenity value of these properties can be attributed to the presence of coral reefs. Degradation of the reefs makes beach front properties less attractive, reduces occupancy rates in hotels, etc. (Gustavson et al, 2000). And a decline in reef quality together with high nutrient levels can lead to algae blooms that reduce the property values along the coastline, as will be discussed in the Kihei case study later in the report.

- *Cultural services*: Native Hawaiians have traditionally had a special cultural and spiritual attachment to the ocean and the reefs as part of the marine system. Most

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[6] See also: K.E. McConnel and T.C. Haab (2001) *Small boat fishing in Hawaii: Choice and economic values*. SOEST 01-01, JIMAR Contribution 01-336. Pelagic Fisheries Research Program, University of Hawaii, Honolulu. & M.P. Hamnett and W.S. Pintz (1996) *The contribution of tuna fishing and transhipment to the economies of American Samoa, the commonwealth of the Northern Marina Islands, and Guam.* SOEST 96-05, JIMAR Contribution 96-303, Pelagic Fisheries Research Program, University of Hawaii, Honolulu.

[7] See also: C. Brown and L. Young (2001) *Proceedings of the Marine Ornamentals '99.* Waikoloa, Hawaii, November 16-19, 1999; & H.W. van Poollen and A.M. Obara (1984) *Hawaii's marine aquarium fish industry profile*. Studies on Marine Economics No.3, University of Hawaii Sea Grant College Program, Honolulu.

residents of Hawaii share these views to some extent, and coral reefs and the sea are an important part of daily life in Hawaii. Though not very tangible, this is a clear 'service' that reefs provide to residents. The traditional Ahupua'a system shows this clearly. This service has been selected as a priority service for valuation even though it is more difficult to quantify than the other goods and services.

- *Biodiversity*: Hawaii is home to a great number of endemic species and many visitors are attracted to this biodiversity. Pharmaceutical companies are interested in exploring bio-prospecting. Valuing biodiversity in economic terms is, however, difficult, as it tends to be interconnected with other values. For instance, tourists are interested to see biodiversity, but exactly how much of tourists' expenditures is biodiversity-related, is difficult to say. In this study, we will attempt to come up with a specific separate value of biodiversity through survey questions and estimates of expenditures by government agencies and NGOs on coral reef research in Hawaii.

3.4 Valuation techniques

For the economic valuation, these different benefits need to be quantified and put in monetary terms. A host of valuation techniques is available to value the goods and services provided by the coral reefs ecosystem. Standard techniques in micro-economics and welfare economics rely on market information to estimate value. However, for most externalities inherent to environmental issues, standard techniques such as market prices cannot be used. Table 3.2 gives a listing of the most common techniques used for valuing the goods and services of coral reef ecosystems.

Table 3.2   Valuation techniques for goods and services of coral reefs

Technique	Goods and services
Directly applicable market techniques	
- Loss of earnings / Human capital approach (HC)	tourism/recreation
- Change in Productivity / Effect of production (EoP)	fisheries/ornamental use/tourism
- Stock (houses, infrastructure, land) at Risk (SaR)	coastal protection
- Preventive expenditures (PE)	coastal protection
- Compensation payments (CP)	fisheries
Revealed preference techniques	
- Replacement costs (RP)	coastal protection
- Travel-cost approaches (TC)	tourism/recreation
- Property-value and other land-value approaches (PV)	coastal protection
Stated preference techniques	
- Contingent valuation methods (CVM)	cultural services, etc. biodiversity

Source: Adapted and shortened from Dixon (1988), Barton (1994).

Three general categories are distinguished: (i) generally applicable techniques that use the *market directly* to obtain information about the value of the affected goods and services or of direct expenditures; (ii) *revealed preference* methods that calculate external benefits indirectly by using the relationships between environmental goods and expenditures on market goods; (iii) *stated preference* methods ask the individuals their willingness to pay (WTP) for the environmental good directly by using structured questionnaires. The WTP is defined as the maximum amount of money a person is willing to pay to obtain a good or service.

We will here specifically discuss five methods, which are also used in the study. These techniques are the Effect on Production (EoP); Replacement Costs (RC); Damage Costs (DC); Travel Costs (TC); and the Contingent Valuation Method (CVM).

Effect on Production (EoP): This technique, also referred to as the 'production function approach' or 'change in productivity' method, looks at the difference in output (production) as the basis of valuing reef services. The technique mainly applies here to fisheries and tourism (producer surplus), for instance to estimate the difference in value of productive output before and after the impact of a threat or a management intervention. Coral mortality may lead to fewer dive tourists and therefore lower tourism revenues. Hence, the change in net profit (i.e. effect on 'tourism service' production) can be calculated, and this can be used as a proxy for the loss in tourism value. For fisheries, the technique is used to calculate net fisheries revenues or the loss in the fisheries value from a specific threat, such as coral mining or the gain in the fisheries value from a management intervention, such as the introduction of a marine reserve. The main challenge is the calculation of the changes in productivity in physical terms between the 'with' and 'without' scenario.

An example of the EoP method is Alcala and Russ (1990), who report on a decline of US$ 54,000 in the total yield of reef fishes off Sumilon Island (Philippines) after breakdown of protective management. McAllister (1998) gives estimates of reef productivity for reefs in excellent condition (18 mt/km2/yr) as well as good condition (13 mt/km2/yr), and fair condition (8 mt/km2/yr). Based on changes in condition over time and estimates of net profits associated with these yields, McAllister estimates the fisheries loss in the Philippines at US$ 80 million per year.

Replacement Costs (RC): The replacement cost approach is used to value the ecosystem service of coastal protection. Data on investments to control coastal erosion are used as a proxy for the coastal protection service of a health coral reef. Hence, the cost of replacing the coral reef with protective constructions, such as revetments and underwater wave breakers are used.

A study quoted in Spurgeon (1992) indicates that on Tarawa Atoll in Kiribati, coastal defenses costing US$ 90,720 had to be built to prevent coastal erosion. Berg et al. (1998) give a detailed analysis of the replacement costs following years of coral mining in Sri Lanka. The average cost varies between US$ 246,000 and US$ 836,000 km^{-1} of protected coastline. Cesar (1996) quotes a case in Bali, Indonesia where coastal protection expenditures of US$ 1 million were spent over several years for 500 m of coastline protection. Finally, Riopelle (1995) cites information on a hotel in West Lombok that has spent US$ 880,000 over a seven year period to restore their beach stretch of around 250 m, allegedly damaged by past coral mining.

Damage Costs (DC): In the absence of coastal protection, the monetary damage to property and infrastructure from surge and storms can be enormous. Hence, the damage cost approach uses the value of the expected loss of the 'stock at risk' as straightforward proxy for the value of the coastal protection service.

Berg et al. (1998) use the cost of land loss as a proxy for the annual cost of coastal erosion due to coral mining in Sri Lanka. Depending on land price and use, these costs are between US$ 160 and US$ 172,000 per km of reef per year. Cesar (1996) uses a

combination of the value of agricultural land, costs of coastal infrastructure and houses to arrive at a range of US$ 90 up to US$ 110,000 per km of reef per year.

Travel Costs (TC): This approach is often used to estimate the welfare associated with the recreational use of a National Park. The travel time or travel costs are used as an indicator of the total 'entry fee', and therefore, a person's willingness to pay for visiting a Park. The further away people live from the Park, the higher the costs are to visit the Park. Because of the variation in these costs among visitors, the demand for different prices can be determined and a 'demand curve' for the Park can be constructed and the associated consumer surplus can be determined. This surplus represents an estimate of the value of the environmental good in question (e.g. the National Park).

An example of TC is Pendleton (1995) who uses this method to estimate the value of the Bonaire Marine Park in the Caribbean. To obtain the welfare estimate, Pendleton divides the number of visitors from each state/country by the population of the corresponding origin. This visitation rate is then regressed upon travel costs, giving the demand curve for reef-oriented vacations to Bonaire. Based on this estimated demand curve, the travel costs from each region and assuming annual visits to the marine park to be 20,000, the total consumer surplus of visitors to the Bonaire Marine Park is approximately US$ 19.2 million annually. Another example is a TC-study reported in Hundloe et al. (1987), with a value of A$ 144 million per year for tourists visiting the Great Barrier Reef. In the US, Leeworthy (1991) has arrived at a estimate of US$285 to US$426 per tourist in Pennekamp Coral Reef State Park in the Florida Keys.

Contingent Valuation Method (CVM): In the absence of people's preferences as revealed in markets, the contingent valuation method tries to obtain information on consumers' preferences by posing direct questions about willingness to pay and/or willingness to accept. It basically asks people what they are willing to pay for a benefit, or what they are willing to accept by way of compensation to tolerate a loss. This process of obtaining information may be carried out either through a direct questionnaire/survey or by experimental techniques in which subjects respond to different stimuli in 'laboratory' conditions. Sought are personal valuations of the respondent for increases or decreases in the quantity of some goods, contingent upon a hypothetical market.

An example of CVM on coral reefs is Spash (2000). Visitors to Montigo Bay (Jamaica) and Curacao (Netherlands Antilles) were surveyed to investigate the consumer surplus, or individual utility, of coral reef improvement. The survey instrument was designed to capture the "non-use" benefits of marine biodiversity, for both local residents and for visitors. The question to respondents dealt with their willingness to pay for an increase in coral cover in the Park. The WTP value obtained was heavily dependent on whether respondents believed that marine systems possessed inherent rights, or that humans had inherent duties to protect marine systems. Such preferences would increase WTP by up to a factor of three. Another example is Dixon et al. (1993). They arrive at an average WTP (over and above expenditures) of US$ 325,000 for Bonaire Marine Park.

3.5 Baseline and scenarios

The main questions to be addressed in relation to coral reef management and damage assessment include the following: (1) What is the economic value of a coral reef

ecosystem? (2) Is it worth managing the coral reef? In other words, do the benefits of coral reef management exceed the costs? (3) In case of an incident, what is the total compensation that the responsible company or individual should have to pay? In other words, what are the total rehabilitation costs and what are the foregone benefits of the incident? And (4) is it economically rational to rehabilitate the reef? In other words, do the avoidable foregone benefits exceed the costs of rehabilitation? These questions are addressed in the following paragraphs.

(1) What is the economic value of a managed coral reef ecosystem?

The first objective of the project is to determine the total economic value (TEV) of the coral reefs of the State of Hawaii. This value can be estimated separately from the management costs. In this case, the values of compatible uses of the various reef functions need to be summed (see discussion above). This value gives an asset value for a natural resource (*in casu*: coral reefs) or for a specific site (e.g. Hanauma Bay). Figure 3-3 gives net (compatible) benefits per year over time. In this specific case, the benefits grow over time, possibly because of increased use or scarcity. The TEV is discounted sum of benefits over time, or put differently, the area under the benefit line.

a. Unmanaged coral reef   *b. Managed coral reef*
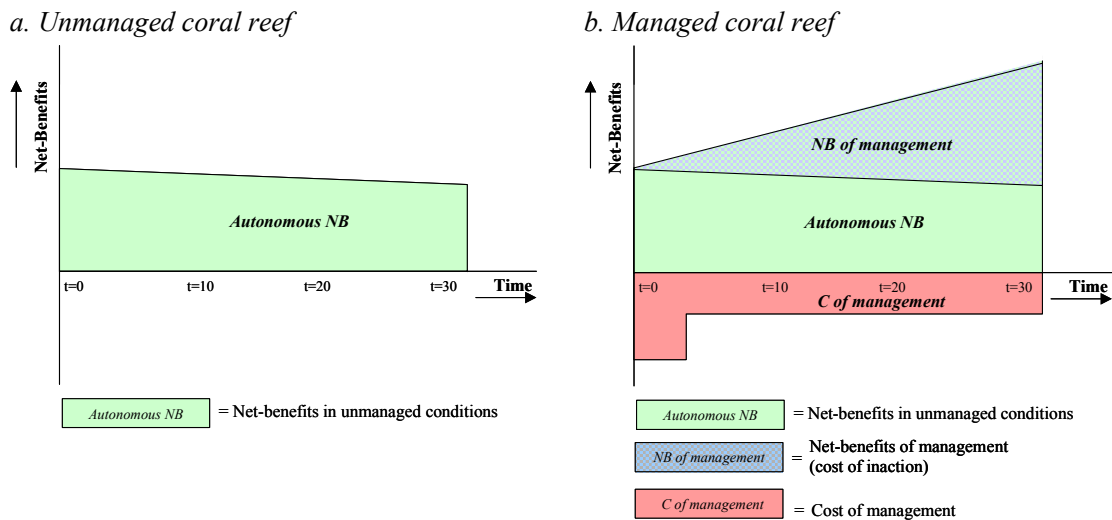
Figure 3-3 Net benefits of reefs over time

(2) Is coral reef management economically justified?
Assuming that the total benefits of the coral reef would not be realized without proper reef management, the benefit stream of the 'with management' scenario can be compared with the benefit stream of the 'without management' scenario. This was done in Figure 3-3. The additional benefits of reef management (*i.e.* the triangle between the two curves) should be compared with the costs of reef management. As long as the additional benefits outweigh the associated costs, management is economically efficient. For specific examples of a cost-benefit analysis of reef management, see Pendleton (1995), White et al. (2000) and Cesar et al. (2000).

(3) What is the total damage related to an incident?

For natural resource damage assessment in reef areas, the economic valuation of coral reefs is a first step to determine losses. Damage claims basically have two main

components: (i) the cost of restoring the damaged resource to its original state; and (ii) the compensation of interim losses from the time of damage until full recovery. Figure 3-4 shows both the restoration costs as well as the interim costs (referred to as unavoidable natural resource losses).

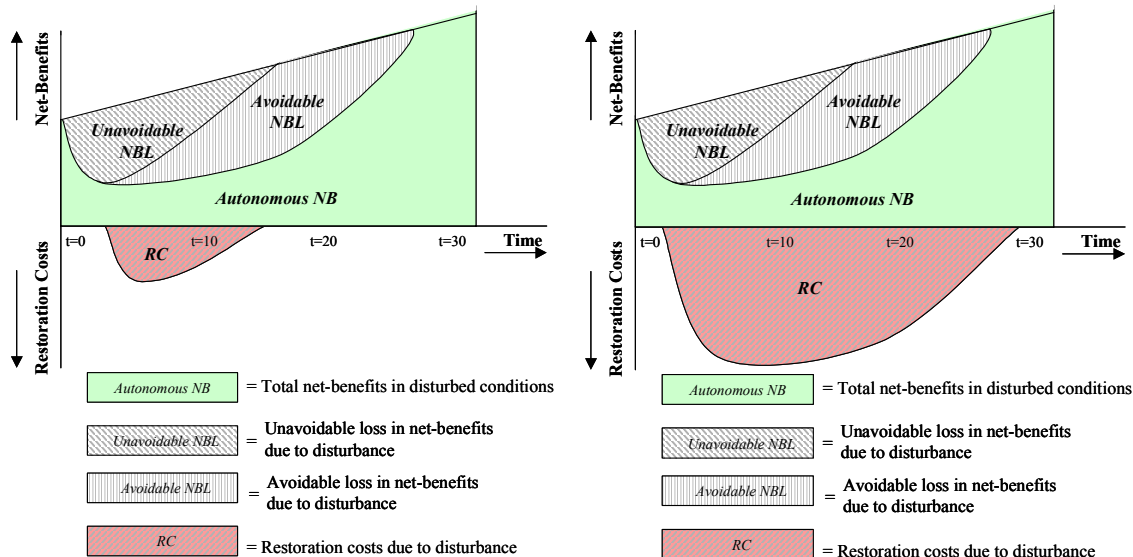*a. Low rehabilitation costs*   *b. High rehabilitation costs*

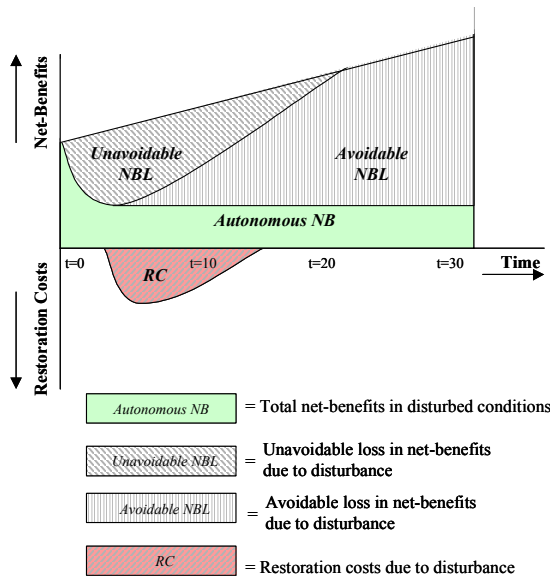*Rehabilitation costs < avoidable net-benefits loss*   *Rehabilitation costs > avoidable net-benefits loss*

Figure 3-4 Damage assessment costs for low and high rehabilitation costs

In the absence of intervention, natural recovery could take place in this hypothetical case but complete recovery would take much longer. The additional foregone natural resource benefits in this case are referred to as the 'avoidable natural resource losses'. Unless the restoration costs are exorbitant (*case b*), damage claims based on the sum of restoration costs and compensation of interim losses are both economically justified and fair. The interim losses need to be assessed on a case-by-case basis and depend on the extent of damage incurred by the goods and services that a coral reef ecosystem provides at that specific site. It will in any case be lower than the Total Economic Value of the area affected. Restoration costs vary also considerably. Cases in Florida show that these can range from $550 to over $10,000 per square meter (Spurgeon and Lindahl, 2000).

Figure 3-5 shows a similar situation but without natural recovery. This could be the case where the hard reef substrate is damaged in a way that makes it difficult or impossible for new coral larvae to settle, due to the presence of rubble or sediments in combination with tidal water movement. Again, two situations are possible. In case *a*, rehabilitation costs are relatively small, and in case *b*, these costs are very high. In this case, it is less straightforward to say whether rehabilitation is justified.

So far, we have excluded uncertainty. In general, both the unavoidable and avoidable natural resource losses are difficult to assess. This is true for the ecological and the economic assessment alike. There can be major uncertainties with respect to possible ecological phase shifts with enormous implications for property values of adjacent coastal areas. In this case, even rather high restoration costs seem economically justified. Whether the court settlements from the damage claims should actually be used for restoration or rather for more general coastal zone management is an open question.

a. Low rehabilitation costs *b. High rehabilitation costs*

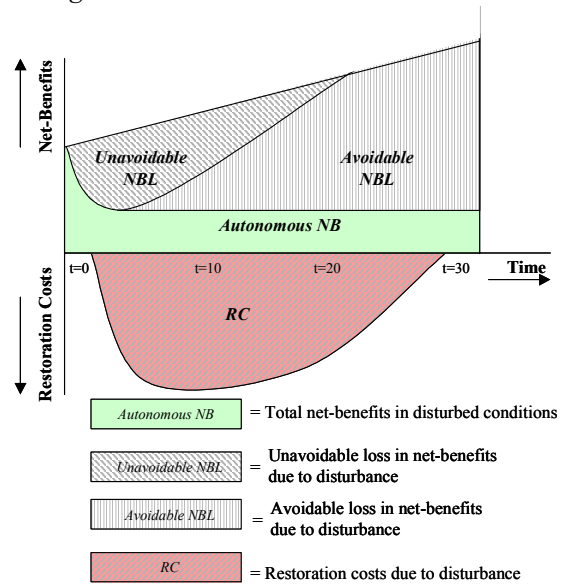| Autonomous NB | = Total net-benefits in disturbed conditions |
Unavoidable NBL	= Unavoidable loss in net-benefits due to disturbance
Avoidable NBL	= Avoidable loss in net-benefits due to disturbance
RC	= Restoration costs due to disturbance

Figure 3-5 Damage assessment costs without natural recovery

3.6 Data collection to quantify costs and benefits

In order to obtain the data for the various benefits and costs for the sites and the management options, data have been obtained from a number of different sources. These will briefly be discussed here.

Dive shop survey

All operating Dive shops and clubs have been approached to get a better understanding of the magnitude of the scuba and snorkel industry. The type of information obtained includes: (i) number of snorkelers and scuba divers; (ii) popularity of dive locations; (iii) total market size (resident vs. visitor distribution); (iv) diver preferences (coral, fish, clear water, turtles...); and (v) availability of coral, fish for current and future demand. The questionnaire itself to interview the dive shops and clubs as well as a summary of the results is presented in the Appendix.

Survey on real estate and the hotel/condo business

A survey was conducted on the Kihei coast that addresses two issues. First, an assessment was made of the damage costs for various stakeholders related to the algae problem. Second, the potential remediation costs of the algae problem were examined. The survey compares economic parameters of the ocean front condominiums in North Kihei affected by chronic algae problems with economic parameters of comparable, but unaffected, condominiums complexes in South Kihei. In particular we concentrate on the difference in room rates, occupancy rates and property values. Data were collected at fifteen relatively large condominium properties containing 745 units.

Tourist and resident survey

Roughly 450 tourists and residents have been interviewed at various locations to retrieve specific information about their perception of different types of coral habitats. The SMS survey bureau was contracted to carry out these surveys. Two types of approaches were followed. First, face-to-face interviews were held with snorkelers and scuba divers as well as with other tourists and residents at the airport and other selected locations. Second, snorkelers, divers and others were handed out a card with internet-address, inviting them to go fill out a questionnaire on the internet on their last diving experience. The questionnaire for the divers and snorkelers as well as the survey results are described in the Appendix.

The main goal of the survey was to (i) understand the purpose(s) for visiting Hawaii; (ii) test the attitude towards (un)healthy reef, (iii) obtain data to carry out a travel costs estimate related to diving/snorkeling and the related consumer surplus and (iv) obtain data to estimate the WTP for better/healthier coral. In order to retrieve reliable answers, the questionnaire explained the causes of the current decline in the health of the reef and how it could be improved.

Fisheries survey

For the aquarium fisheries along the Kona coast, semi-structured interviews were conducted with aquarium fishermen and wholesalers. This was carried out by a UH-student, Jan Dierking, in conjunction with DAR on Big Island (Bill Walsh). The interviews aimed at determining the gross value of aquarium fisheries along the Kona coast, the various costs involved, as well as standard fisheries data on catch, catch composition, price, catch per unit effort, etc. The results are presented in the Chapter describing the Kona case study.

Benefits transfer

It is too costly, however, to obtain all relevant data through original data collection for the whole of Hawaii. For the case study sites, major data collection was carried out to determine the precise TEV of coral reefs of these locations. If there are other, comparable, areas for which no such field data are available, these values might, if carefully done, be extrapolated from another area. If an extensive study has been carried out for the fisheries and tourism potential in marine protected area in Hawaii, than it is not unlikely that these values can form a proxy for another marine reserve elsewhere in Hawaii. This practice of transferring of monetary values is called as 'benefit transfer'.

Literature review and key informants interviews

One of the main sources of economic values and data related to coral reefs ecosystems is the extensive collection of literature available. Given the traditional interests in coral reefs ecosystems of Hawaii, detailed knowledge is available with various local experts and policy makers. The research team conducted elaborate interviews with key informants in order to retrieve data as well as to gain their interest in the study. Besides, government statistics were used where needed (e.g. official DBEDT tourism statistics and DAR fisheries data).

4. The model

In order to deal with the environmental and economic complexities, a simplified dynamic simulation model has been developed. This model incorporates the ecological-economic relations by following a pathway, linking the type of coral reef ecosystem and its uses and location with the physical goods and services provided by this reef type and the economic value of these values. To simplify the overall pathways, the model is presented in separate modules that are mutually connected. These include:

- Ecological module
- Tourist module
- Amenity module
- Fisheries module
- Biodiversity module

4.1 Ecological module

Coral reefs are among the most diverse and productive ecosystems on Earth. They are found in the warm, clear, shallow waters of tropical oceans worldwide. Coral reefs provide shelter and food for a large variety of organisms. Indeed, the foodweb on a reef is extremely complex. Corals and coral reefs are rather sensitive to certain disturbances and even slight changes in the reef environment may have detrimental effects on the health of entire coral colonies. These changes may be due to a variety of factors. These can be categorized as natural disturbances and anthropogenic disturbances. Although natural disturbances may cause severe changes in coral communities, anthropogenic disturbances have been linked to the vast majority of decreases in coral cover and general colony health when coral reefs and humans occur together (Turner, 2000).

One of the greatest threats to coral reefs is human expansion and development. As development continues to alter the landscape, the amount of freshwater runoff increases. This runoff may carry large amounts of sediment from land-clearing areas, high levels of nutrients from agricultural areas or septic systems, as well as many pollutants such as petroleum products or insecticides. Whether it is direct sedimentation onto the reef or an increase in the turbidity of the water due to eutrophication, decreases in the amounts of light reaching corals may cause bleaching and mortality (Brown and Ogden 1993). In addition, increases in the amounts of nutrients enhance the growth of other reef organisms such as algae that may out-compete corals for space on crowded reefs.

In addition to runoff, outflows from water treatment plants and power plants are the cause of much damage to coral reefs. Sewage treatment facilities can greatly increase the nutrient levels surrounding their outflow pipes while large power plants increase water temperatures by discharging cooling water into the coastal waters. As with all these factors, the pressure for the continued degradation of coral reefs is exacerbated by the increasing size of the human population.

As this population increases, so does the harvest of resources from the sea. Due to overfishing, reef fish populations have been greatly decreased in some areas of the

world. The removal of large numbers of reef fish shifts the ecological balance on reefs and allows macro algae, once controlled by large grazing fish populations, to become dominant on reefs in many regions. Due to decreased yields, fishermen have been forced to change their catch methods in order to get enough fish to sustain their needs. In some areas this has led to the introduction of fish traps and nets with small mesh diameters that catch even the small juvenile fish. In other areas of the world, the use of explosives or poisons has become quite common (Richmond 1993). Not only do these practices kill all fish in the affected areas, but they severely damage the reefs habitat that these fish rely on as well.

The complexity of the ecology of coral reefs makes it difficult to model these processes in a realistic manner. To simulate the numerous interdependencies and the multiple threats to coral reefs requires a huge modeling effort with enormous data needs. Even then, it leaves us with large scientific uncertainties. On the other hand, ignoring the ecological processes in the analysis is also undesirable. Therefore, we have developed a simplified ecological model, referred to as SCREEM (Simple Coral Reef Ecological Economic Model) on the basis of existing knowledge and literature. The basic structure of this model is shown in Figure 4.1.
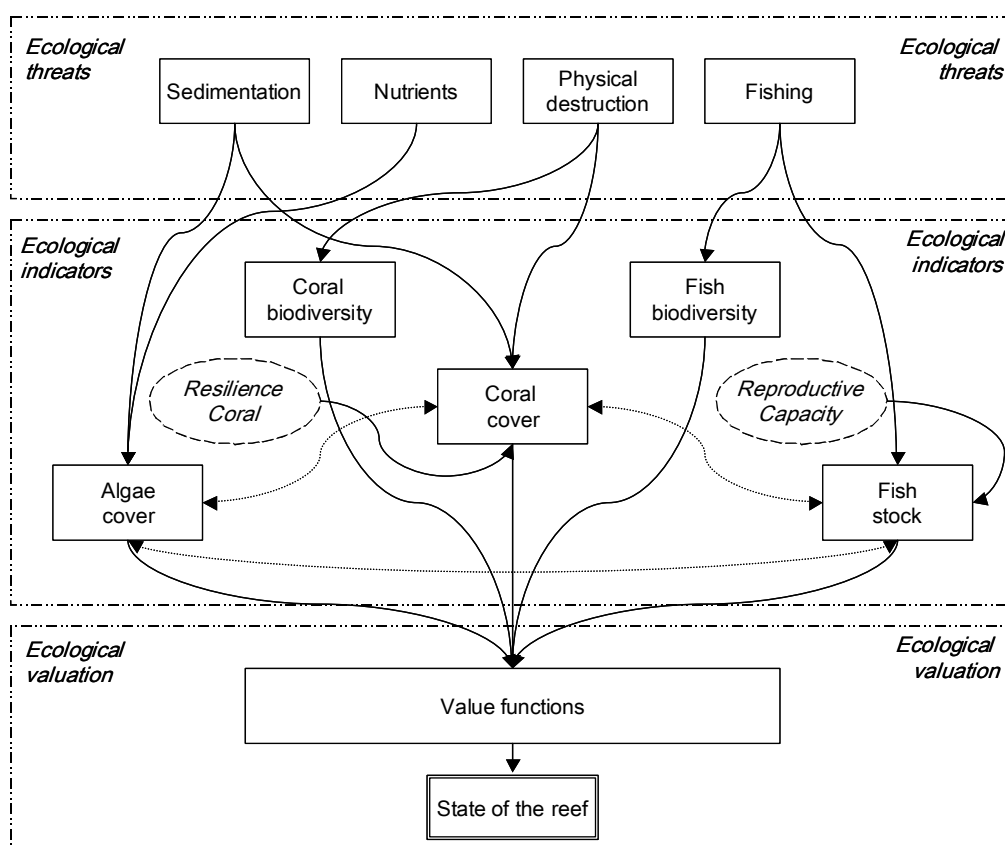
Figure 4.1   Ecological sub-model

The model consists of five ecological indicators that represent the most important environmental characteristics of a coral reef. These are: coral cover, coral biodiversity, fish stock, fish biodiversity and macro algae cover. These variables are exogenously determined for the first year of the analysis and endogenously modified over time. To present these ecological indicators in a workable manner, and to connect them to the

economic modules, a composite indicator is constructed: "the state of the reef" indicator. The following sequential steps are undertaken:

- Step 1: Normalize the individual ecological indicator scores into a score between 0 and 1. For example, in a country where the maximum coral cover is 60% and the minimum is 0%, these levels are defined as 1 and 0 respectively. A coral cover of 30% is then interpolated linearly with a score of 0.5. The relationship between the normalized score and the indicator is called the value function. Although this function can have different shapes, in our model this function is assumed to be linear.

- Step 2: The normalized individual scores are aggregated by attaching weighs to the indicators that represent the relative ecological importance of the indicator as compared to the other indicators. In Hawaii the following weights have been applied: coral cover (30%), coral biodiversity (20%), fish stock (20%), fish biodiversity (15%) and the macro algae cover (15%). These weighs are based on expert judgments.

- Step 3: Test how the "state of the reef" indicator, which by definition is between 0 and 1, behaves over time.

Box 1. Resilience of coral reefs

Resilience is a scientific concept, which states that an ecosystem, such as a coral reef, can find itself in different states of equilibrium, each with differing structures and functions. Subjected to a disturbance the ecosystem can jump over to a new state of equilibrium with a new structure and new functions. Holling (1986) asserted that an ecosystem that does not jump over to a new state of equilibrium after a disturbance, staying instead in its original position is one that has resilience. In other words, an ecosystem that has a good buffer capacity against disturbances can be called resilient.

When a coral reef is subject to some form of natural disturbance such as a storm, or toxic discharge, or some other man made disruption, pieces of coral break off or die. After such a disturbance the reef can develop in several different ways. If the coral reef has a broad biological diversity of plants and animals carrying out a variety of functions then the buffer capacity is usually high. When a disturbance hits and certain species are temporarily taken out of the system there are other species able to take over and fulfill their functions. The coral consequently has the opportunity to gradually grow back after the disruption. If the coral reef's capacity to cope and organize itself during both the disturbance and rebuilding phase is good (see The Ecosystem) then the reef is said to be resilient.

If, however, the reef is already under pressure due to over fishing and overfeeding and has few fish species, its buffer capacity come a disturbance is low. The coral's functions are not as easily replaced and thus risks losing its position in the system to fast growing algae. The reef then finds itself in a new state of equilibrium dominated by algae instead of coral and with totally new functions. In other words the coral reef lacked resilience.

To allow for regional modifications, a resilience factor has been integrated into the model. The concept of resilience is explained in Box 1. Rather than measuring the

resilience we interviewed several Hawaiian reef experts to derive a normalized score between 0 and 10 to take into account the resilience of the reef.[8]

To understand how the individual threats are having an impact on the different ecological indicators, a brief literature review is presented below (the Appendix contains a more elaborate discussion). Given the specific problems in the case studies, we will focus the discussion on eutrophication, sedimentation, physical impacts from dive/snorkel/anchor pressure and overfishing.

Nutrients

The waters surrounding coral reefs are typically oligotrophic or low in concentrations of inorganic nutrients (nitrogen and phosphorous). Under these circumstances, reef-building corals usually dominate and fleshy algae are kept in low abundance because of a combination of both low nutrients and high grazing activity from fish and invertebrate species. It has been suggested that by altering either of these factors (nutrient levels or herbivory), the competitive balance between corals and algae will shift. While there is some evidence that phosphorous may decrease rates of calcification in corals most of the literature suggests that the largest effect of increased nutrients on coral reefs is by the response of the algal community. In some cases herbivores are abundant enough to make up for any differences in algal growth caused by enhanced nutrient supply. Phase shifts from coral to algal dominance are typically believed to be the result of both increased nutrients and reduced grazing pressure as a result of overfishing or disease (Jennifer Smith, pers. comm. 2002). Well-known cases of coral-algal phase shifts are Kaneohe Bay in Hawaii (Smith, et al. 1981) and Jamaica (Hughes 1994)

Sewage pollution as well as run-off from fertilizer use on land and golf courses disturbs the fragile balance between corals, algae and herbivores by nutrient enrichment, which will favor certain species, usually at the expense of reef corals, and will lead to alteration of the reef community structure (e.g. Marszalek, 1987; Grigg and Dollar, 1990; Maragos et al., 1985). Other effects of sewage pollution include toxicity from herbicides and heavy metals as well as sedimentation and high biochemical oxygen demand among others (Grigg & Dollar, 1990; Pastorok & Bilyard, 1985). However, most of the impacts from sewage pollution on coral reefs reported in the literature relate to the nutrient enrichment rather than to toxic effects. Literature suggests threshold levels for dissolved inorganic nitrogen (DIN) of 1.0 mM and for soluble reactive phosphorus (SRP) of 0.1 mM (see for example Lapointe et al., 1997).

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[8] "To precisely measure a coral reef's resilience is difficult, if not impossible according to the Professors Carl Folke and Nils Kautsky who lead the studies in resilience and coral reefs at Stockholm University. They suggest that we should examine the biological diversity of the coral reef. A coral reef with many species having similar eating habits and methods of breeding fulfil similar functions in the ecosystem and therefore can replace each other in the event of a disturbance. It is also important to find out where the different species live and if they are able to move from one area to another if required. That a species may move around both within the coral reef and between other reefs is of considerable importance if the reef is to remain in a coral dominated state of equilibrium after a disturbance. A coral reef with many species functioning in a similar way and able to easily move from place to place is one that has good signs of resilience." Holmlund, 2001.

In the Appendix, the exact modeling of the effects of nutrients on coral cover and biodiversity on the one hand and algae cover on the other hand is discussed. Field data from Barbados (Tomascik and Sander 1985, Tomascik and Sander 1987, Wittenberg and Hunte 1992), Brazil (Costa, et al. 2000), Curaçao (Gast 1992, Gast 1998, Gast, et al. 1998, Gast, et al. 1999), Kaneohe Bay (Smith, et al. 1981, Hunter and Evans 1995) and Reunion (Naim 1993) were used to distil relationships between nutrients and coral cover and the number of coral species. For instance, the number of scleractinian corals decreases with eutrophication, as is shown in Figure 4.2.
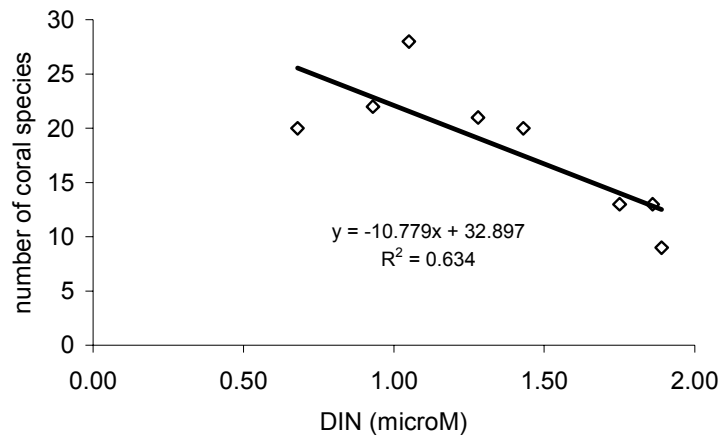

The scatter plot shows the number of coral species on the y-axis (0 to 30) versus DIN (microM) on the x-axis (0.00 to 2.00). The fitted line equation is:

$$y = -10.779x + 32.897$$
$$R^2 = 0.634$$

Figure 4.2 Decreasing number of stony coral species with increasing DIN concentration. Data from Curaçao and Barbados (see references above).

Sedimentation

Sedimentation resulting from anthropogenic influences occurs almost always concommitant with eutrophication. Major reviews of anthropogenic disturbances on reefs (Pastorok and Bilyard 1985, Grigg and Dollar 1990, Richmond 1993, Dubinsky and Stambler 1996) both address sedimentation and eutrophication. In practice, both are usually the result of urbanization, coastal development and changes in land use (e.g. deforestation). It is often difficult to separate the individual effects of the two influences (Walker and Ormond 1982, Tomascik and Sander 1985, Tomascik and Sander 1987, Tomascik and Sander 1987, Tomascik 1991, Bak and Nieuwland 1995, Connel 1996). However, it is clear that sedimentation alone is an important threat to the health of coral reefs. Rogers (1990) associates dredging in the Caribbean with construction of hotels, condominiums, runways, roads, harbors, navigation channels, military installations, and beach replenishment. She states: "Unprecedented development along tropical shorelines is causing severe degradation of coral reefs primarily from increases in sedimentation."

Background levels of sedimentation on reefs that are not influenced by human activities are between 1 and 10 mg per cm^2 per day (Rogers, 1990). She suggests that chronic sedimentation rates above 10 mg per cm^2 per day are "high". The relevance of this threshold is shown in Kenya, where sedimentation values of 1.35 and 4.25 mg/cm^2/d did not lead to differences in coral cover (McClanahan and Obura 1997). Sudden exposure to heavy sedimentation may result in burying of corals, expulsion of the symbiotic algae from the coral polyps ("bleaching"), and subsequent death. Other effects of increased sedimentation (varying from 200 to 800 mg per cm^2) include: reduced growth, reduced calcification (33%), decrease in net production, and increase in respiration. Coral species

respond differently to heavy sedimentation and some are more efficient in rejecting sediment than others. Bak and Elgershuizen (1976) found that *Acropora palmate, A. cervicornis, Porites astreoides* and *Agaricia agaricites* were the least efficient and *Colpophyllia natans, Diploria strigosa* and *Madracis mirabilis* were among the most efficient. Chronic exposure to higher concentrations of sediment can have a variety of negative impacts on corals, many of which can be attributed to reduced light levels (Rogers, 1990). Dose response relations of the effects of sedimentation are discussed in the Appendix. Finally, reef degradation is also partly responsible for a decline of reef fisheries. Sedimentation can kill major reef-building corals, leading to the eventual collapse of the reef framework. The reduction in the percentage of living coral as well as the decrease in the amount of shelter that the reef provides leads to a decline in the number of reef fish and the number of species (Rogers, 1990).

Physical destruction by diving and snorkeling activities

The diving and snorkeling industry causes damage to the reef in two ways: (1) through direct interaction of the divers and snorkelers with the corals; and (2) through anchoring and boating damage. Several authors have researched and documented the direct snorkeler and diver damage. However, it is often difficult to distinguish such damage from natural damage or other forms of human-induced damage (for example, see Rogers et al., 1988). Examples of direct snorkeler and diver damage studies are Rogers et al. (1988a, 1988b) in the Virgin Islands National Park and Biosphere Reserve (VINP), Tilmant (1987) and Tilmant and Schmahl (1981) in Biscayne National Park, Florida, and Talge (1991) in the Looe Key National Marine Sanctuary, Florida. For a recent summary of dose-effect relationships, see Wielgus et al. (2002). Below, we will come up with a simple estimate for the average physical destruction of corals by divers and snorkelers.

The studies on diver impact have given some indications –although far from unequivocal- on ecological carrying capacity of reefs for recreational diving. Examples include Harriott et al. (1997), Hawkins and Roberts (1994, 1997), Epstein et al. (1999), Dixon et al. (1993), Chadwick-Furman (1997) and Scura and Van't Hof (1993). These and other aspects of physical damage by divers and snorkelers on reefs are further discussed in the Appendix. Physical damage to reefs and reef corals from motor boating and yachting (e.g. anchoring), as well as ship groundings are also discussed there.

Overfishing

Overfishing, though not directly destructive to coral reefs, can have severe impacts on the coral reef ecosystem. Most major fisheries in the world are heavily overfished with severe consequences for local populations and the economy. Reef fisheries tends to be more prone to overfishing than, for instance, pelagic fisheries. Overfishing is different from the other threats described here, in that it does not have the same type of direct destructive impacts. Modest forms of non-destructive overfishing will, in fact, have very little impact on corals. Extreme forms of non-destructive overfishing could, on the other hand, alter the ecosystem balance, ultimately leading to a reef dominance by sea urchins or macro-algae and resulting in a dramatic drop in fishery yields and reduced coral biomass and productivity (McClanahan, 1995).

An interesting example of overfishing of invertebrates is given by a case of mother-of-pearls (Trochus spp.) in a village in Central Maluku (Indonesia) (Figure 4.3). A traditional management scheme, referred to as *sasi*, was in place with three year harvesting cycles. At some stage, annual harvesting was allowed, leading to severe overfishing of the resource. In the time of the 3-year closed season, the average yield was around 3400 kg (over 1100 kg per year). In the time of annual collection since 1987, the average annual yield of just over 400 kg.
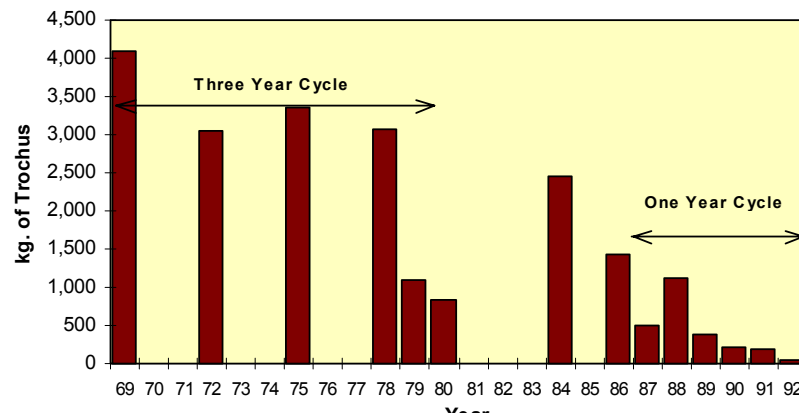

Figure 4.3   Yield of Trochus Shells in Noloth (Central Maluku, Indonesia) in 1969-1992
(source: data gathered from village head at Noloth, Maluku, as presented in Cesar et al. 1997).

Alcala & Ross (1990) describes an interesting case where protective fishery management was discontinued and where fishery yields dropped very quickly after the resource was re-opened for use. This is the same experience as in Hawaii where fisheries were re-opened after World War II with trophy catches during the first year. A comparison of fish standing stock in the Main Hawaiian Islands (heavily fished) versus the Northwest Hawaiian Islands (no fishing) also shows a dramatic difference (Friedlander & DeMartini, 2002).

Overfishing can lead to such a reduction in grazing fish that the balance between corals and macro-algae is altered, potentially even causing to a phase shift in time (Hughes et al. 1994). This has been discussed above in the discussion on nutrients. For more information on fisheries, see the Fisheries Module described below.

4.2 Tourist module

Some 200,000 divers and more than 3 million snorkelers enjoy the Hawaiian reefs every year. They pay a substantial amount in direct and indirect expenditures to admire the unique marine life. Thereby they support a large aquatic tourist industry. In 2002, more than 100 dive and snorkeling operators where registered in Hawaii, earning between US$ 50 and 60 million per annum. But the recreational expenditures related to coral reefs extend much further than the direct dive and snorkel related revenues. Bus and taxi drivers bring tourist to popular destinations such as Hanauma Bay, hotels lodge these same tourist and restaurants feed them after a long day in the water. Therefore, calculating the recreational benefits involves much more than simply adding up the value added of the dive and snorkel industry.

Figure 4.4 shows the conceptual composition of the reef-related recreational benefits. The supply curve is positively slope because more dive and snorkel trips will be supplied if the revenue is high. The demand curve is negatively sloped because the demand is high at low prices and will drop if the prices increase. Demand and supply will match at the equilibrium indicated by *e,* which is a combination of price *p* and *q* number of tourist that will go snorkeling or diving.[9]

Both producers and consumers benefit more from this situation than in a situation where no trips were sold. In fact, the consumers as a group would have been willing to pay as much as the area *ceq0* but instead only are paying as much as *peq0*. The consumer surplus in this situation is the shaded triangle *cep*. A similar situation holds for the producers who would have been willing to offer their services at a value equal to the area *qe0*. Instead they receive as much as *peq0* of revenues. In other words, their benefit is equal to the shaded triangle *pe0*, indicated as the producer surplus. The recreational value of coral reefs in Hawaii is equal to the sum of the consumer and the producer surplus.
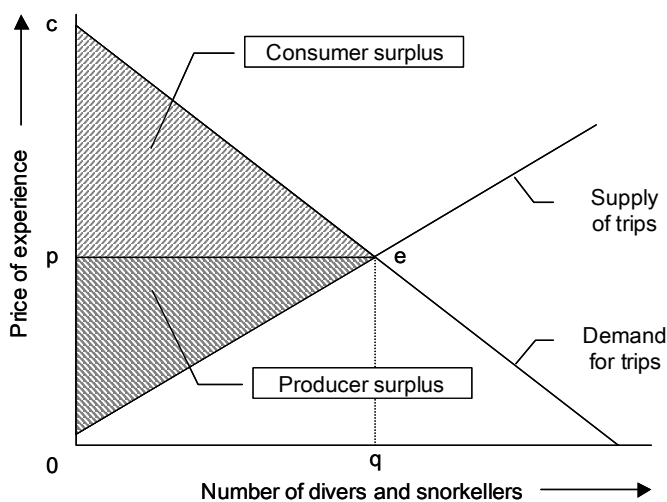
Figure 4.4 Conceptual composition of the recreational benefits

To calculate the consumer surplus, in other words, the amount the visitors would have been willing to pay in addition to the actual payment to enjoy the Hawaiian reefs experience, two approaches have been followed. On the hand, we determined the consumer surplus of divers and snorkelers that use the Hawaiian reefs by applying the contingent valuation method as well as the travel cost method (see Section 3.3 for more elaborate explanation of these methods).

To calculate the producers surplus we have considered the value added of the direct and indirect expenditure related to marine activities. The actual expenditure directly related to snorkeling or diving experience includes entry fee, hiring of mask and fins, bus fare etc. We assume that only 25% of these expenditures can be considered as value added. The expenditures indirectly related to the marine experience such as hotel costs and

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[9]   For the sake of simplicity, the supply and demand curves have been drawn as linear curves but could very well have a convex shape.

travel costs. DBEDT (2001) reports that marine activities such as diving and snorkeling form 18% of the total motivation of visitors to come to Hawaii. Again we assume that for the hotel expenditures, only 25% can be considered as value added for the Hawaiian economy. For the ticket costs of the air fair this value added rate is only assumed to be 2%. Finally, we add the multiplier of the real expenditures. We have adopted the multiplier for tourism in general on Hawaiian economy of 1.25 developed by DBEDT (2001).

To determine the dynamics of the recreational benefits, the above prices and quantities for 2001 are fed into the model. Figure 4.5 shows the overall structure of the tourist module. An important assumption in the model is the relationship between the growth rate and the "State of the Reef". Both the dive industry survey and the diver and snorkel survey indicted the dependency of marine activities on the quality of coral reef ecosystems (see Appendix). If the quality of the reef worsens further over time, fewer tourists will decide to go snorkeling or diving. In fact, the growth rate may even become negative at a certain given quality level of the coral reefs[10]. The last step in the tourism module is the summation of the consumer and producer surplus for both the diving and snorkeling activities into the total recreational value.
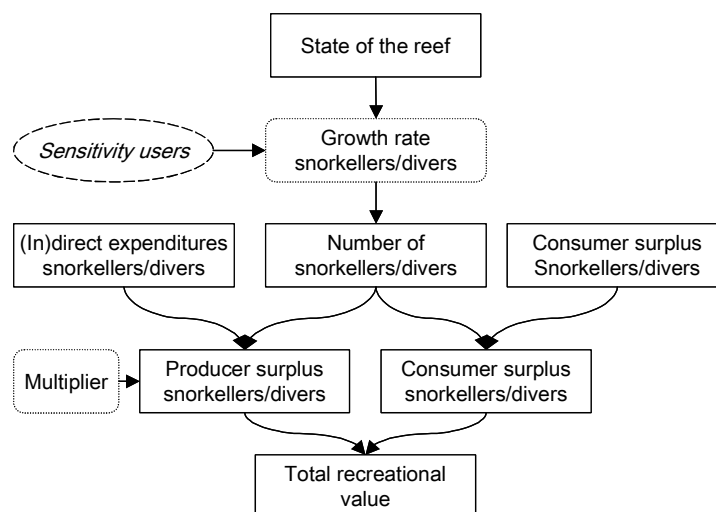
Figure 4.5   Tourist sub-model

4.3 Amenity module

Houses, hotels and condo's in the vicinity of a healthy marine system are generally more valuable than comparable properties that are not close to the coast. The view of a clean beach and a healthy coral reef are perceived as a benefit to those that can enjoy it every day. Also, the presence of a healthy reef is more likely to prevent beach erosion and indirectly serves as a form of coastal protection. Therefore, beachfront houses at a beautiful coast with clean beaches and healthy coral reefs generally sell for a significantly higher price. Likewise, condos and hotel rooms adjacent to healthy marine systems generally operate at higher room and occupancy rates.

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[10]   Because divers and snorkelers have a different level of sensitivity with regard to the quality of the reef, a distinct elasticity have been applied for each user group.

To accurately capture this amenity-associated value a hedonic pricing method on room rates and house prices would have to be conducted. Through this method, the surplus value of houses and hotel rooms in the vicinity of healthy marine systems can be measured. Combining this with the number of the residential houses, condo's and hotel rooms leads to a positive amenity value attributable for a healthy coral reef. On the basis of the expert judgment of real estate agents we assume that 1.5% of the sale price of the properties is attributable to the marine ecosystem. This is shown by the outer part of Figure 4.6.
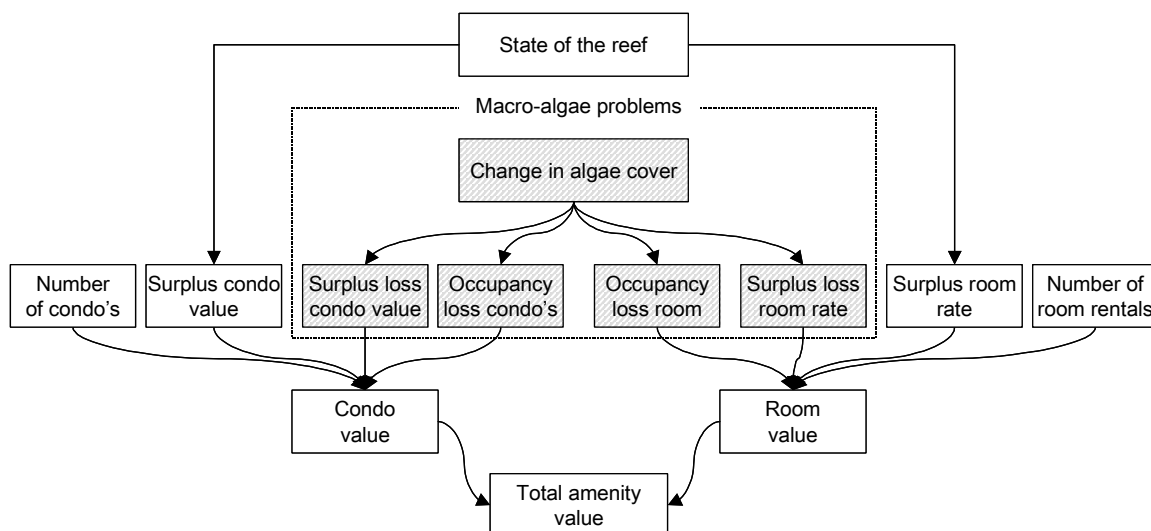
Figure 4.6   Amenity sub-model

In the case of a negatively impacted coral reef ecosystem, such as seen at North Kihei in Maui, this positive value will be much lower. The macro-algae problem at the Kihei coast is believed to cause a negative impact on property values of the affected condominiums as well as the rental prices and vacancy rates in transient accommodation. Therefore, in addition to the positive value attributed to the positive aspects of a coral reef, negative impacts are occurring as a result of the coral-linked algae problem. This additional negative impact on the amenity value has been indicated in Figure 4.6 by the shaded segment.

Chapter 6 presents the Kihei Coast case study, which specifically addresses the issue of positive and negative effects of coral reefs in different states of health on the amenity value.

4.4 Fisheries module

The fisheries module distinguishes four types of fisheries: (i) commercial fisheries; (ii) subsistence fisheries; (iii) aquarium fisheries; and (iv) recreational fisheries. Aquarium fisheries are taken separately from other commercial fisheries given their rather unique characteristics. Given our focus on reef-associated fisheries, the reef-dependency of each type of fishery needs to be determined. For aquarium fisheries, this dependency is 100%. For commercial fisheries, typically only a fraction of total catch is reef related, especially in areas where the major fisheries are offshore. The reef-dependency together with the fish catch and fish price gives the total gross value of reef-associated fisheries for each of

the four types of fisheries. Incorporating the costs and labor input give the value added from fisheries. Figure 4.7 shows the elements that form the fisheries module.
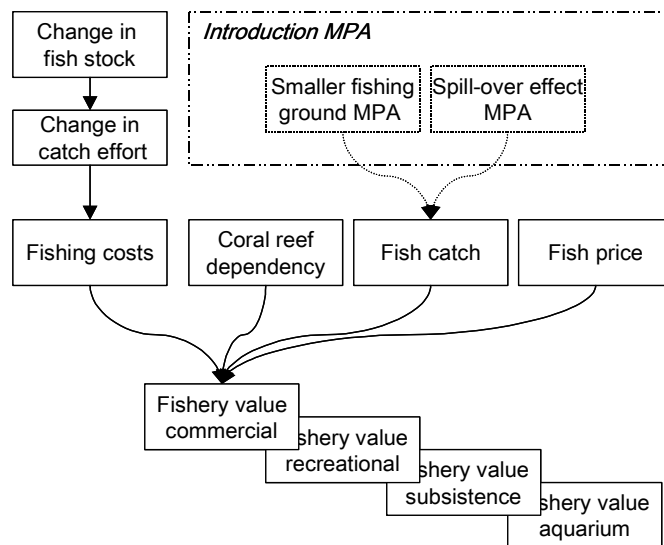

Figure 4.7   Fisheries sub-model

The fish catch depends on a number of different factors, such as the fish stock (e.g. this stock can increase because of coral recruitment and associated additional fish habitat) and the level of effort. These issues can also effect the fishing costs. The interactions between fish stock and level of effort can be highly complex, as is well-known from the bio-economics literature. Here, we have taken a very simple approach where numbers from the literature and field data information are used to calibrate the model.

Management interventions can alter fish catch as well. An example is the introduction of Marine Protected Areas (MPA), discussed above (see Birkeland and Friedlander, 2002 for a recent report in Hawaii). A well-enforced MPA implies that fisheries will be restricted in specific areas (e.g. no-take zones) and possibly better managed in buffer zones and other adjacent areas.[11] Yet, total fish catch in the remaining area can increase or decrease depending on the specific level of the larval and adult spill-over effects.

The data for Hawaii used in the fisheries sub-model are described below. Commercial marine landings in Hawaii are estimated at 12 million kg (12,000 mT) with a value of US$ 55.9 million (1999 figures, DAR). That number has been fairly stable over the period 1994-1999. For the years 2000 and 2001, landings show much more variation with a value of US$ 43.7 million in 2001 and US$ 60.5 million in 2000. Therefore, the 1999 figures are used as reference point for our further calculations. Tuna and billfish together form 78% of total commercial marine landings in value terms. Landings and value per fish family for 1999 are given in Table 4.1.

Of total marine landings, only inshore fisheries as a portion of the category 'others' are coral reef-associated. The 'others' category includes lobster (47% of 'others' in value terms), shrimp (14%), shark (10%), crabs (7%) and octopus (3%). We assume that of the category 'others' 50% is reef-associated. This gives a total value of US$ 1.5 million for reef-associated commercial fisheries in Hawaii.

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[11]   See Rodwell and Roberts (2000) for an overview. See also Section 4.1 for a discussion.

Table 4.1   Commercial marine landings (in weight and value) in Hawaii 1999.

Species group	Quantity	Total value	reef dependency	Reef-associated fisheries value
	(MT)	*(million $)*	*(%)*	*(million $)*
Tuna	6,349	31.0	0	0
Billfish	2,812	12.5	0	0
Misc. pelagic	1,467	5.8	0	0
Deep bottomfish	302	2.4	0	0
Akule/Opelu	571	2.0	0	0
Inshore fish	894	0.6	100	0.6
All other (squid, lobster, etc.)	131	1.8	50	0.9
Total	196	55.9	2.7	1.5

Source: DAR (2000) website.

Actual fisheries landings are substantially larger than the statistics above suggest, partly because of underreporting of commercial fish landings. Also, subsistence and recreational fishery without licensing requirements are substantial: studies suggest that the recreational/subsistence catch may be equivalent or larger than commercial catch (Gulko et al. 2001 and studies cited there). Research by Friedlander et al. (1995) in Hanalei Bay (Kauai) suggests that total catch there is five times higher than the official government statistics by the Division of Aquatic Resources. Assuming conservatively that recreational/subsistence catch is equivalent to commercial catch (see above), we take the real reef-associated fisheries gross value to be US$ 3.0 million per year.

The value added for reef-associated fisheries cannot be readily derived from the gross values given above. General data for sectoral GDP of Hawaiian fisheries should not be used, given the large difference in capital intensity between offshore fisheries and inshore fisheries. Our own findings for aquarium fisheries in Kona show a value added of 60% of gross value. Because of lack of other data, we use this percentage for total reef-associated fisheries. This means that value added of reef-associated fisheries is 60% of US$ 3 million or US$ 1.8 million.

Around 3800 fishermen are involved in commercial fisheries. It is not clear how many of these are focusing on reef-associated fisheries. However, if we take the percentage reef-associated fisheries in value terms (2.7%) as proxy for the percentage of fishers in this sub-sector, we come to a total of around 100 commercial fishermen in reef-associated fisheries. Reef-associated fisheries per island are unknown. Government statistics only give totals per island and species level for the whole of Hawaii.

4.5 Biodiversity module

The existence of a great number of endemic species makes the Hawaiian coral reefs a unique natural resource. This reef biodiversity aspect generates economic benefits. Figure 4.8 shows the main components of the so-called biodiversity module. These include the scientific or research value, the non-use value and the bioprospecting value.
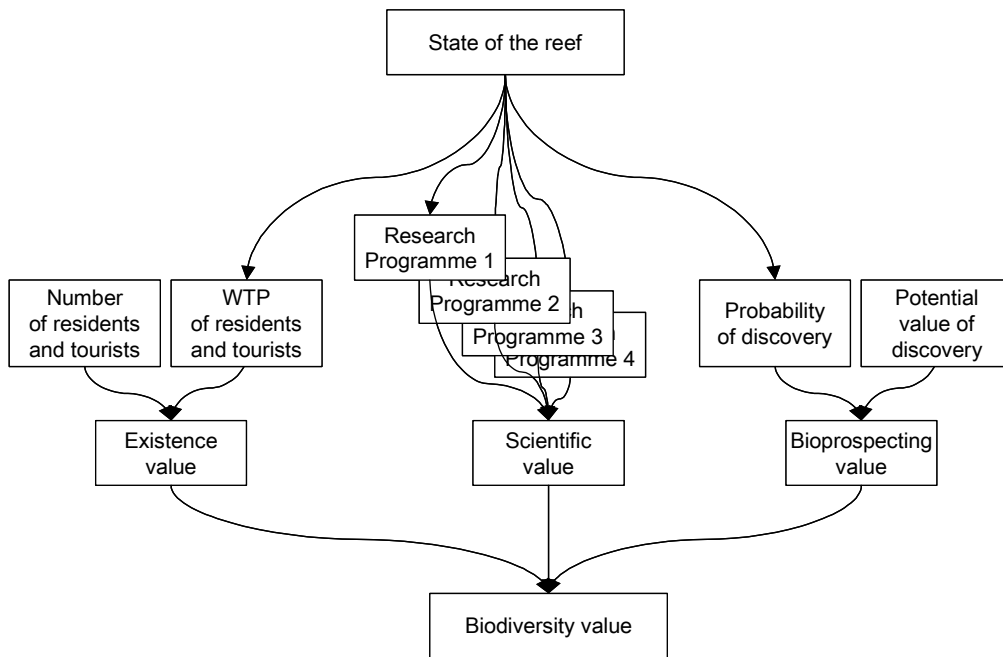
Figure 4.8 Biodiversity sub-model

The bioprospecting value refers to the revenues pharmaceutical companies may be able to retrieve from the diverse genetic pool contained by the Hawaiian coral reef. Because no company is presently active in this field, we do not consider this value for the Hawaiian context.

The research value is determined in a rather straightforward manner. All research budgets that are assigned to coral reef ecosystems in Hawaii are included in this value category. To determine this value a brief survey was held. All potential research candidates were asked to provide us with their annual budget for 2001.

Non-use values are based on the fact that people are willing to pay some money amount for a good or service they currently do not use or consume directly. In the case of the Hawaiian coral reefs they are not current visitors but derive some benefit from the knowledge that the reef exists in a certain state and are willing to pay some money amount to ensure that actions are taken to keep the reef in that state.

Sprugeon (1992) indicates two factors, representing the supply side and the demand side, that have a significant impact on the magnitude of the non-use values of coral reefs: (1) Values are positively related to the quality and uniqueness of the coral reef on both national and global scales. This supply side factor implies that the existence of many other similar sites would reduce the value. For the Hawaiian reefs it can be claimed that on the one hand the reef is unique because of the presence of a large number of endemic species, but on the other hand is not special because of the relatively limited number of species. (2) The size of the population, and their level of environmental awareness, will be positively related to non-use values. This demand side factor implies that the Hawaiian reefs are in relatively great non-use demand. Most reefs in the world are located in developing countries and therefore have a rather poor and uneducated audience.

To determine the non-use value for the Hawaiian reefs we adopt the approach used by Leeworthy and Wiley (2000). In their study for the Tortugas Ecological Reserve they calculate a non-use value assuming that 1% of the US population would have a willingness to pay for the reserve. They apply three values, $3, $5 and $10 per household per year. From our own survey we found that the involvement of Hawaiian residents with coral reefs is very high. Therefore we assume that for this group, all households have a willingness to pay of $10 per year. For the remaining group, the mainlanders, only 1% have a non-use value of the lower bound, $3 per household per year. The results of the analysis are shown in Chapter 8.

5. Tourist overuse at Hanauma Bay, O'ahu

Hanauma Bay is part of the Ko'olau mountain range that was formed on the east side of the island of O'ahu. Subsequent to the end of the volcanic activity that formed the main range, the north-east side of the crater collapsed and fell into the sea, leaving the Pali cliffline as evidence of this giant landslide. After the eruptions that formed the Ko'olaus there was a period of volcanic quiet lasting for at least two million years.

Figure 5.1   Areal photograph of Hanauma Bay

Hanauma Bay is diverse in marine habitats. Tidepools are evident in shallow waters at the reef edge. The reef at Hanauma Bay is a fringing reef, one that grows along the shoreline. As elsewhere in Hawai'i, the greatest contributor to the reefs are calcareous red algae that secrete a hard material cementing accreted substances to the underlying substrate. The back reef area is located near the sandy beach and is composed largely of sand or coral rubble. This reef flat has been extensively modified by anthropogenic activity. Photographs by Chester K. Wentworth depicting the coral cover in 1926 are evidence of the decline in coral cover on the inner reef flat. The fore reef or reef front protects the beach from erosion by absorbing most of the wave energy. A spur and groove region creates channels to further dissipate the wave force. The deeper reefs with more extensive coral cover extend out to the mouth of the bay to 30 meter depths.

Hanauma Bay Marine Life Conservation District (MLCD) established in 1976, was the first MLCD in Hawaii. In Hawaii, MLCDs are designed to conserve and replenish marine resources and state laws restrict the taking of Marine life in MLCDs. MLCDs provide fish and other aquatic life with a protected area in which to grow and reproduce. Snorkeling, diving, underwater photography, and other similar passive activities are allowed in MLCDs.

5.1 Background

Ecological conditions

The CRAMP program conducted video transect on 3 and 10 meters depth in 1999 and 2000. The main results have been summarized in Table 5.1. The video transect data on 3 and 10 meters depth reveal that Hanauma's coral cover rank is 24 and 23 among 60 reefs in Hawaii, respectively. Coral stayed roughly the same between the 2 sampling periods. Macroalgae coverage is very low at around 2%. A high percentage of crustose coralline

algae and turf algae and a moderate percentage of fine sediments with high content of terrigenous material was measured at both depths. No rare or unusual species were observed.

Table 5.1   Data on coral reef for Hanauma Bay (1999/2000)

Species	Mean at 3 meter depth	Mean at 10 meter depth
Coral cover	25.8 %	27.0 %
Species Richness	7	4
Species Diversity	0.48	0.74
Macroalgae	1.5 %	2 %

Source: CRAMP 1999/2000

The CRAMP study also monitored the fish populations (see Table 5.2). Among 60 reefs, Hanauma Bay at 3-meter depth ranked 33th in species richness, 24th in density, 44th in biomass, and 33th in diversity. Hanauma Bay at 10-meter depth ranked 10th in species richness, 17th in density, 17th in biomass, and 10th in diversity. The most abundant species were the Hawaiian sergeant (*Abudefduf abdominalis*) and the Goldring surgeonfish (*Ctenochaetus strigosus*) at the 3-meter and 10-meter reefs respectively. The species with the highest biomass were the Spectacled parrotfish (*Chlorurus perspicillatus*) at the 3m and 10m reefs respectively. *Sebastapistes coniorta* presence notable as this species is not common to sites surveyed.

Table 5.2   Fish data for Hamauma Bay 2000

Species	3 meters	10 meters
Density (#/125m²)	417	630
Biomass (g/125m²)	38,663	43,022
Species Richness	59	61
Species Diversity	1.99	2.45

Source: CRAMP 1999/2000

Economic conditions

The Hanauma Bay Nature Preserve is one of the most heavily used marine preserves in the world, currently drawing over one million visitors per year. Figure 5.2 shows the growth of the number of visitors in the last three decades. The estimate is based on headcounts at approximately two hour intervals taken by water safety officers over an eight hour work day. Data is from June 1 to May 31 for each year (Hawaii State Data Books 1970-2000). These data may be somewhat unreliable as the counts are not exact and are taken by different water safety officers.

In 1975 68% of visitors were local residents while that percentage in 1990 was 13% (Sano 1990). A 1977 estimate of 'recommended optimal use level' for Hanauma Bay was 1,363 persons a day (330 persons allotted for the upper picnic area, 408 for the lower grassy area, and 625 on the sandy beach). This implies half a million visitors in total of which 225 thousand people use the beach (Mak and Moncur, 1998).
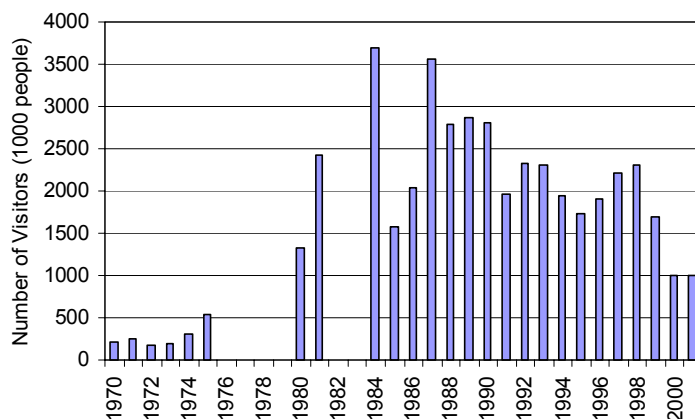
Figure 5.2   Annual number of visitors at Hanauma Bay

In 1995, the City Council of the City and County of Honolulu passed ordinance 95-36 which placed a $5 admission charge on non-Hawaii residents over the age of 13. The ordinance went into effect July 1, 1995. In 1996 the City Council amended these rules by implementing a voluntary donation system where non-Hawaii residents over the age of 13 are now charged $3 to enter the bay and everyone is charged $1 to park in the parking lot above the bay. The ordinance went into effect on April 25, 1996. Parking fees are also charged to tour buses. As a result of the above sources of income, the financial situation of Hanuama Bay are looks very bright. Table 5.3 shows the revenues generated by the C&CH from Hanauma Bay entrance fees, concessions and parking fees.

Table 5.3   Revenues from Hanauma Bay

Year	entrance	parking	concession
1994-1995			$403,000
1995-1996	$2,160,736	$275,000	$361,000
1996-1997	$769,765	$76,299	$372,000
1997-1998	$2,480,446	$244,072	

Threats

Hanauma Bay has experienced very high levels of human use over the past 35 years. Primary impacts have been through fish feeding, trampling of corals, and structural change of the reef through the installation of a submarine cable. In the late 1980s, O'ahu's Hanauma Bay Nature Preserve was almost being visited to death. At peak times 13,000 people a day visited the beach. These crowds stirred up sediment, trampled on the corals and algae, dropped trash, fed the fish and left a slick of suntan lotion on the bay's surface. Areas of management concern include the impact of visitors on the reef and biota, impact of fish feeding, and the "carrying capacity" in visitor numbers of the site.

Interventions

On April 28, 1999 the City Council approved funding for a study of the park's capacity to handle visitors (Wright, 1999). A ban on fish feeding at Hanauma Bay was to become effective on April 15, 1999, but the city and State of Hawaii agreed to delay enforcement for approximately 3 months so that Dr. Brock, who is in charge of the study, can

measure the "before" and "after": effects as part of his study. Aquatic Biologist Alton Miyasaka of the DLNR expects that the following changes will occur when feeding is curtailed:

- Fish populations will shift away from dull nenue (rudder fish) and pualu (surgeonfish) that thrive on artificial food supply and currently dominate the inshore reef.
- The nenue and pualu will be replaced by more colorful weke (goatfishes), parrotfishes, butterfly fishes and damselfishes.
- There may be a decline in numbers of fishes, but reduction in larger fishes may be made up by increases in number of smaller fishes.
- Because the change will be gradual, no mass die-offs of any kind are expected.

The numbers of eels, which feed on other fish, may also gradually decline.

Besides reducing the number of visitors, the importance of improving the behavior and awareness of the visitors was recognized as important. In 1989, Hawaii Sea Grant joined county and state park administrators to establish the Hanauma Bay Educational Program (HBEP). With a funding allocation from the Honolulu City Council, the Hanauma Bay Educational Program is now housed in a new interpretive educational kiosk atop the crater rim where more than a million visitors a year can learn about coral reefs, geology, oceanography, fishes and conservation. The new education center opened up in August 2002. Besides helping to educate bay visitors, the education center helps establish bay etiquette and creates a sense of stewardship for the bay's marine resources.

More specifically, the following measures accompany the installation of the education center: banning smoking, removing pigeons, improving sewage system to prevent sewage and washroom runoffs into the bay, and moving the food concession to the upper park level could raise the threshold stress tolerance level to a higher level, thus allowing the park to accommodate more visitors. Educating visitors on proper behavior at the park – e.g., don't walk on the reef; put sun-screen on the body at least 20 minutes before entering the water – could further lower the degradation of the bay's ecosystem.

The costs of the new center are rather large. The initial investment of building the education center was $13.5 million and operating the center is estimated to cost around half a million US$ annually. Many believe these costs exceed the benefits that can be generated by the center. To investigate this issue, a case study has been conducted at Hanauma Bay with the prime goal to: (a) determine the value of the reef at Hanauma Bay, and (b) evaluate the effectiveness of the investment in the education center in terms of costs and benefits.

5.2 The survey

Little is known about the behavior and perception of divers and snorkelers in Hawaii. Tabata and Reynolds (1995) report on the diving industry in 1990 only from a macro perspective. The profile of divers and snorkelers in Hawaii has never been systematically studied. To fill this gap, a survey was conducted in late 2001 and early 2002 by the survey bureau SMS Research. The Appendix provides a full overview of the survey.

The sample population was the active user group of coral reefs in Hawaii. In total 50 divers and 260 snorkelers were interviewed. In addition, 150 non-users were surveyed

using a short version of the interview to investigate differences in perception between users and non-users. At Hanauma Bay 152 interviews were conducted. Of these, 97 surveys were self-administered, i.e., respondents were handed surveys which they filled out and returned them to the interviewer.

The main purpose of the survey was to determine the average profile of each user group in terms of (i) actual expenditure directly attributable to the diving or snorkeling trip, (ii) the consumer surplus for this experience and (iii) the willingness to pay for a healthier marine environment. To determine the consumer surplus for the actual experience, the following question was formulated. "*If everything -- fish, coral, water, the experience -- was the same, what do you think would be the maximum you would be willing to pay for that experience?*". Next respondents were shown a card that contained the following options to choose from: 'the amount you paid', '$1 more than you paid', '$5 more than you paid', '$10 more than you paid', '$30 more than you paid' and '$50 more than you paid', '$1 less than you paid', '$5 less than you paid', '$10 less than you paid', '$30 less than you paid' and '$50 less than you paid'.

Next, the respondent was asked to have a look at two sets of pictures (see Appendix) and indicate which set of pictures was closer to what the respondent had experienced on the last dive or snorkel trip? Next, the following text was read to respondent "*Let's say the State of Hawaii had a marine life preservation program that protected corals, reef fish, and reef animals. This would help us have healthier coral and more marine life. The result would be like photo set A. Without this program, the reefs would look more like photo set B.*" Then the following question was read to the respondent "*With this program and with a healthier marine environment, what do you think would be the maximum you would be willing to pay for your scuba diving or snorkeling experience, including a fee for marine life preservation?*" The same payment card was shown to assist the respondent in selecting an amount.

The results of this evaluation are shown in Figure VI.14. The real expenditures provide a predictable pattern. Residents generally spend much less on their dive or snorkel experience because they often have their own gear and also have less transportation costs to access the site. The consumer surplus for the same experience, without any environmental changes, is also largely predictable. As shown in Figure 5.3 these are proportional to the real expenditures of the different user groups.

To determine the environmental component of the WTP question, the consumer surplus has been subtracted from the WTP value obtained for a healthier marine environment. The surprising result is that the environmental component is much larger for the snorkeler ($2.69 per snorkeling trip) than for the diver ($0.44 per dive). In the first instance one would expect the more advanced diver to have a higher WTP to protect the marine environment than the snorkeler. An explanation for this unexpected result is that divers has already high costs and therefore are less willing to increase their expenditures solely for the sake of marine conservation. Another explanation is that divers, who are generally more acquainted with marine protection than snorkelers, are more skeptic about the effectiveness of marine conservation programs. Residents have a relatively high willingness to pay for marine conservation ($2.86) most likely because they feel more affiliated to their own reefs than the visitors.
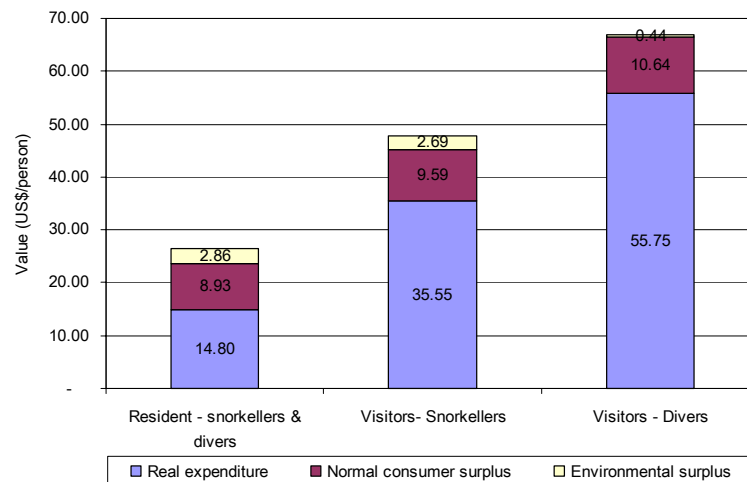
Figure 5.3 Allocation of real expenditures, consumer surplus for the same experience and the surplus payment for a better marine environment

Next, the interviewer asked the respondent whether it is reasonable to insist that scuba divers and snorkelers pay a fee for marine preservation. Only 22% of the respondents felt that it was not the responsibility of the users of the coral reef to keep it in a proper shape. They felt it was a typical responsibility of the state to do this. The majority of the respondents, however, felt that the divers and snorkelers should also, in one way or another, be held responsible for the costs of marine conservation, thereby supporting the polluter pays principle. Typically, when looking at the response of the subgroups divers are more reluctant to take responsibility than snorkelers. One of the reasons for this reluctance is that they perhaps feel that their contribution to the overall problem of reef degradation is limited.

In summary, the survey shows that the users of corals reefs in Hawaii, and Hanauma Bay in particular, are willing to pay much more for their diving or snorkeling experience than they are doing at present. The argument that installing or increasing a user fee with a limited amount (e.g. $1 or $2 per experience) would discourage the user to pursue their activities seems therefore unjustified. In fact, many users feel that it is reasonable to ask some sort of contribution to the users because they are also partly responsible for the damage done to the reef. The admission fee to Hanauma Bay could therefore even be as high as $10 without having a notable impact on the visitor numbers. However, from the view point of equity such a high entry fee may be less desirable.

5.3 Scenario analysis

As mentioned, the main goal of the Hanauma Bay case study is to: (a) determine the value of the reef at Hanauma Bay, and (b) evaluate the effectiveness of the investment in the education center in terms of costs and benefits. To answer these questions, future developments will have to be taken into account. For this purpose the SCREEM model was applied. The time frame of the evaluation is 50 years. Baseline developments have been determined based on a review of the literature and discussions with experts. Moreover, ecological-economic interactions will impact both the state-of-the-reef indicator as well as the economic indicators.

When determining the value of coral reefs at Hanauma Bay, the main question is what future conditions to take into account. The economic value with a specific intervention, such as the implementation of a compulsory education program, is most likely to be very different than the value without an intervention. Therefore we analyzed two distinct scenarios:

- *With education*: The visitors of Hanauma Bay pay their entry fee and stroll through the education stands and go through a compulsory short film that explains about coral reefs in Hawaii and how the visitors should manage these. It is anticipated that physical damage and fish feeding will be considerably less in this scenario;
- *Without education*: The visitors of Hanauma Bay pay their entry fee but do not go through the education stands and are not exposed to a short film about coral reefs. Physical damage to the reef caused by standing on the reef and fish feeding will be continue to occur;

In the following sections, the ecological and economic effects under both scenarios are discussed in more detail.

Ecological effects

The analysis assumes that the number of visitors per year, around 1 million, will remain constant over time. Figure 5.4 shows that this level of visitors is not sustainable if the behavior of snorkelers and divers is not changed. Over a period of 50 years, the coral cover will decline from 27% to 19% in the scenario *without education*. On the other hand, with the education program, ecological improvements to the reefs occur as trampling on and breaking of corals diminish over time. Because reef regeneration takes place very slowly, the recovery of the reef only occurs after 25 years. In other words, with the education program and the present level of 1 million visitors a year, the reef is expected to be in a similar shape, with a coral cover at the current level of 27%.
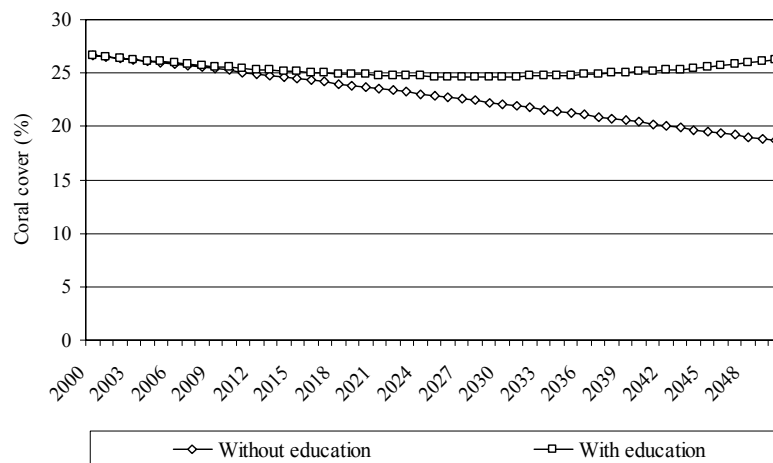
Figure 5.4 Development of the coral cover with and without the education program

This link for Hanauma Bay has been clearly demonstrated by Mak and Moncour (1998). The curve *N* in Figure 5.5 shows the positive relationship between the number of visitors and the stress level of the reef. There are two ways of reducing the stress level from level *A* to level *B*. First, if the behavior of each visitor remains unchanged the number of visitors will have to be reduced from V_1 to V_2. The disadvantage of this approach is that

less people can benefit from the beauty of Hanauma Bay. Moreover, because Hanauma Bay has already reduced the number of visitors from 3 million to 1 million, the general public may not appreciate a second cut in the visitation rate. This may make such a scenario politically unfeasible. The second way of reducing the stress level from level *A* to level *B* is to improve the behavior of the visitors. This has been shown in Figure 5.5 by the shift of curve *N* to *N'*. If the education program is sufficiently effective, the number of visitors can remain constant over time.
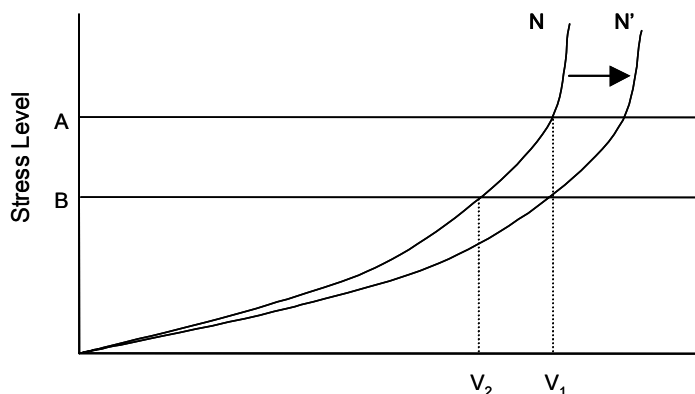
Figure 5.5 Relation between coral pressure, visitor numbers and education

Source: adapted from Mak and Moncur 1998

Economic effects

The main economic effects in the Hanauma Bay case study are (i) an increase in satisfaction of visitors to the bay, (ii) the positive fishery spill-over effect, (iii) an increase in biodiversity value derived from a healthier coral reef, and (iv) the so-called education spill-over effect. This education spill-over effect refers to the fact that snorkelers and divers to Hanauma Bay go snorkeling on average at 2 or 3 other locations in Hawaii and thereby also behave better in those other reef areas. Education therefore not only benefits Hanauma Bay itself but also prevents physical damage to other reefs. The education therefore can be considered a long-lasting investment in environmental awareness and tourist behavior. Most critics of the education center generally ignore this effect and tend to look only at the effects that education has in Hanauma Bay itself.

The earlier reported findings of the survey, shown in Figure 5.3 have been used in the analysis to calculate the recreational benefits of Hanauma Bay. The first step in this procedure is to identify the true user group of the coral reef of Hanauma Bay. After all, not all visitors actually go snorkeling or diving and are therefore not necessarily benefiting from the reef as such. The survey revealed that the most active users were the Europeans of whom 95% went snorkeling or diving. The least active user groups were the Japanese of whom only 60% actually put their head in the water. The total number of active users is estimated over 800,000 people. The calculation of the different nationalities using Hanauma Bay is provided in Table 5.4.

Table 5.4   Geographic profile of visitors to Hanauma Bay

Type of visitors	Total number of visitors to Hanauma Bay	Share of snorkeling or diving	Number of active visitors Hanauma Bay
Residents	150,000	90%	135,000
US West	221,212	90%	199,091
US East	189,627	90%	170,665
Japan	258,651	60%	155,190
Canada	33,848	90%	30,464
Europe	30,680	95%	29,146
Other …	115,982	85%	98,585
Total	1,000,000		818,140

Next, it is calculated how much value can be attributed to this marine activity. We have taken into account four categories. First, we measured the welfare gain of the visitors by determining the consumer surplus. In other words, the amount the visitors would have been willing to pay in addition to the actual payment to enjoy the Hanauma Bay experience. Second, we include the actual expenditure directly related to snorkeling or diving experience. This includes entry fee, hiring of mask and fins, bus fare etc. We assume that only 25% of these expenditures can be considered as value added. Third, we consider a share of the expenditure indirectly related to the marine experience such as hotel costs and travel costs. DBEDT (2001) reports that marine activities such as diving and snorkeling form 18% of the total motivation of visitors to come to Hawaii. Again we assume that for the hotel expenditures, only 25% can be considered as value added for the Hawaiian economy. For airfares this value added rate is only assumed to be 2%. Fourthly, we adopt the multiplier effect developed by DBEDT (2001) of 1.25 for the overall economy. These different categories have been reported in Table 5.5. The current annual recreational value of the coral reefs of Hanauma Bay to the Hawaiian economy is estimated to be $31 million. The largest contributor to this overall estimate is the indirect expenditure of the active visitors of the Bay. Note that this overall benefit substantially outweighs the expenditures on management of Hanauma Bay.

Table 5.5   Recreational benefits of the different users of Hanauma Bay (in US$)

Type of visitors	Aggregate consumer surplus	Direct expenditure attributed to Hanauma visit	Indirect expenditure attributed to Hanauma visit	Multiplier effect	Total recreational value
Residents	1,097,550	708,750	-	177,188	1,983,488
US West	1,542,952	1,891,360	3,263,496	1,288,714	7,986,521
US East	1,322,652	1,621,315	3,565,484	1,296,700	7,806,151
Japan	1,202,725	1,474,309	2,459,600	983,477	6,120,111
Canada	236,093	289,404	707,163	249,142	1,481,802
Europe	225,881	276,886	582,582	214,867	1,300,217
Other …	764,030	936,553	1,926,471	715,756	4,342,810
Total	6,391,883	7,198,577	12,504,796	4,925,843	31,021,099

In calculating the educational spill-over effect, a distinction is made between residents and visitors. As far as visitors are concerned, active visitors on average snorkel 3.8 times during their stay in Hawaii of which 1 snorkel trip will be in Hanauma Bay. The education spillover effect for active visitors is therefore assumed to materialize in approximately 2 snorkeling trips outside Hanauma Bay. In accounting for this spillover effect we adopt the calculations reported in the earlier Chapter 3 on threats to the reefs of a damage rate of 2 cm^2 per trip. In accounting for the spill-over effect for residents, it should be realized that the active residents, who indicated to be snorkeling on average 10 times in a year, will continue doing so for many future years. In other words, the accumulative effect of their education is much larger than for the visitors. Calculations show that improved behavior of snorkelers results in less reef change (4 hectares) than would otherwise take place. For divers, a damage reduction of approximately 0.2 hectares is estimated.

Figure 5.6 shows the aggregated benefits consisting of the recreational values, the education spill-over effects, the biodiversity values and the fisheries spill-over effect. Due to the further degradation of Hanauma Bay if no proper education program is established, the value of Hanauma Bay will slightly decrease to $35 million in 2050. This decline is mainly caused by the reduction of the consumer satisfaction of the visitors. In the "with education" scenario, the value of Hanauma Bay can increase significantly, mainly due to its educational role for general coral reef use in Hawaii. The area between the "with and without education" scenarios represents the cost of inaction. At a discount rate of 4% this area representing the net benefits of education is valued at $100 million. The composition of this amount is determined by the increased satisfaction of visitors to the bay (33%), and an increase biodiversity value derived from a healthier coral reef (4%), and the education spill-over effect (63%).
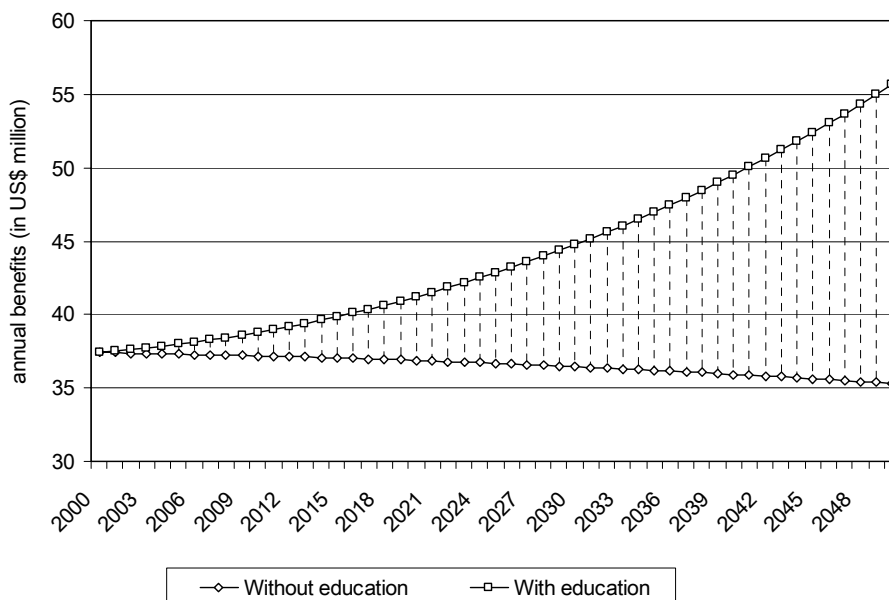

Figure 5.6   The benefit cost ratio of the education program at Hanauma Bay at various discount rates

The additional costs of the education program aggregate over time to an amount of $29 million at a discount rate of 4%. This is far less than the above $100 million net benefits generated by the education program. In other words, because the benefit cost ratio at a 4% discount rate of 3.5 widely exceeds 1 the investment in the education program can be considered economically feasible. Figure 5.7 provides the benefit costs ratio for various discount rates. Only at a discount rate of more than 12% does the benefit cost ratio become less than 1. Under those conditions, the project is no longer economically feasible. It should be realized, however, that besides economic motives there may exist other reasons such as purely ecological or social reasons to pursue the education program.
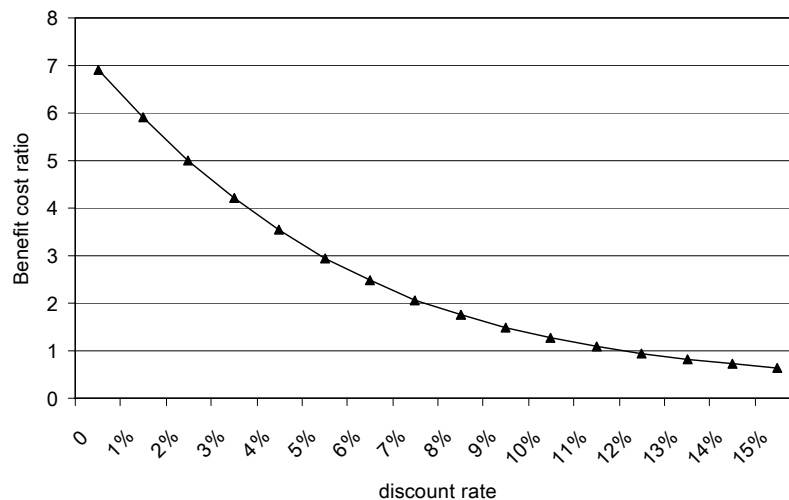
Figure 5.7   The benefit cost ratio of the education program at Hanauma Bay at various discount rates

5.4 Lessons learned

Several typical conclusions can be drawn from the study at Hanauma Bay:

- Visitors to Hanauma Bay are willing to pay much more for their experience (~$10) than they are presently doing. This consumer surplus is even larger if they know this payment is used for conservation (~$12.5).

- Divers are less willing to contribute to conservation than snorkelers (perhaps) because of their high expenditures or their skepticism about its effectiveness.

- The education spillover effect dominates the economic value of the Bay. Other reefs benefit from education at the Hanauma.

- The net benefits of the education program (~$100 million) over time widely exceed the cost of the program (~$23 million) over time.

6. Coastal development at the Kihei coast, Maui

Algae blooms have been a recurring problem on reef flats off the southern and western coasts of Maui for almost ten years; Hypnea, Sargassum, Dictoryota and Cladophora have all dominated reef flat areas on Maui at various times, presumably due to leaching of nutrients from cesspools, injection wells or other non-point sources (Green, 1997; Grigg, 1997). Nutrient enrichment can cause phytoplankton blooms, which limit sunlight necessary for most
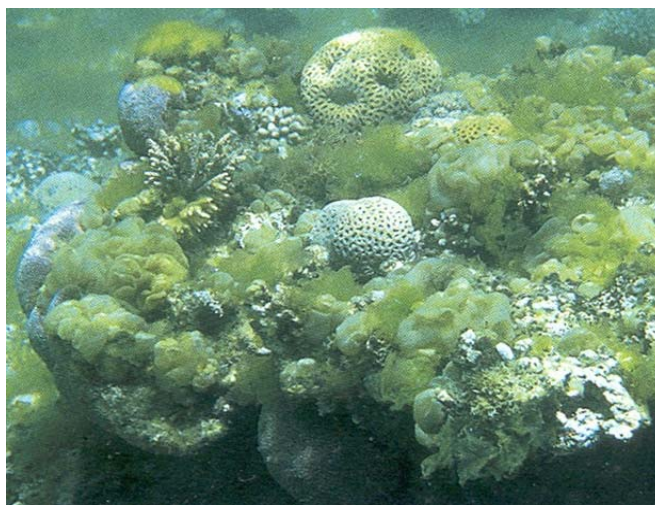
Figure 5.1 Algae problems at Kihei Coast, Maui (Source: Jennifer Smith)

stony corals. Other concerns from runoff and seepage include introduction of bacteria and disease. In this case study, we will attempt to estimate the net-benefits of solving the algae blooms at the Kihei coast of Maui.

6.1 Local conditions

The relationship between algae and the coral ecosystem in the Kihei region has been extensively examined by Jennifer Smith, Celia Smith and Cindy Hunter as part of a larger survey of Maui coral resources (Smith, et al. 2000). In a December 2000 survey Smith found that the North Kihei area had algae cover of over 50%. Of all Maui sites surveyed, only Ma'alaea had a higher algae cover ratio (80%). Smith also surveyed a site in South Kihei ("Kihei Beach") adjacent to numerous condominiums and a shopping area. Algae cover in South Kihei was estimated at ~5%. A significant consequence of a high algae cover is that a competitive threat is posed to coral reef growth and health. Thus, the North Keihi algae problem is both a costly economic nuisance and a direct biological threat to local coral resources.

The cause of the Kihei algae problem is not known. Based on the conclusions of the West Maui Watershed Study several nutrient sources have been identified. Potential contributing sources include wastewater discharge, storm water and agricultural runoff, and golf course runoff. In addition, there are a number of Kihei residents who associate the build up of algae in North Kihei with oceanographic changes from manmade and littoral processes. Because of this knowledge gap we cannot directly relate the cost of intervention with the net benefits to be gained from improved nutrient management. We can, however, calculate what the net-benefits could be if the algae problem was solved. This provides us with some idea about the level of investments that could be justified to reduce nutrient outflow to the reefs.

Marine activities in terms of snorkeling and diving are limited at the Kihei coast. As opposed to many other reefs in Hawaii the main economic benefit of the reef is therefore not so much the recreational value. Instead, the main function of the Kihei reef is the coastal protection and amenity value to the coastal properties. As explained in section 4.4 property value in the vicinity of a healthy reef is found to be higher than property in the absence of a reef or the presence of an unhealthy reef. Especially when the reef plays a role in the occurrence of algae blooms, the reefs impact on property values can actually be negative instead of positive. To study this phenomenon, a survey has been conducted at the Kihei coast.

6.2 The survey

The Kihei coast survey addresses two issues. First, an assessment was made of the damage costs for various stakeholders related to the algae problem. Second, the potential remediation costs of the algae problem have been examined. The study area is shown in Figure 6.2.
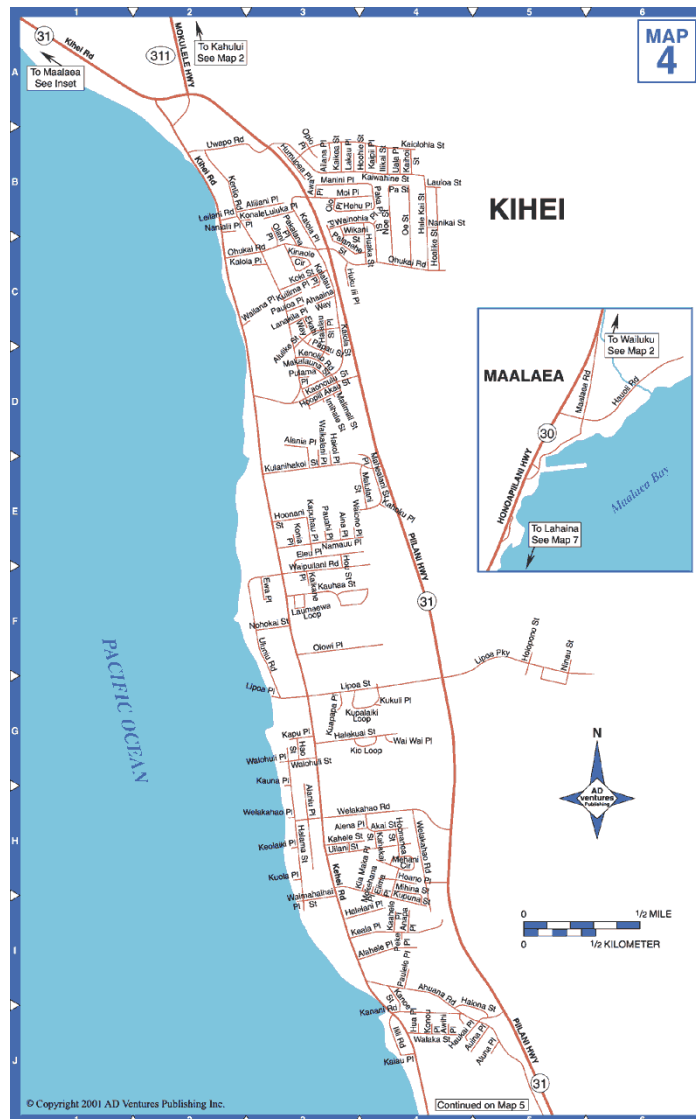

Figure 6.2   Study area at the Kihei Coast, Maui

Damage cost

The macro-algae problem at the Kihei coast has a negative impact on property values of the affected condominiums as well as the rental prices and vacancy rates in transient accommodation. To study this impact a survey was conducted in early 2002 that compares economic parameters of, on the one hand, the ocean front condominiums in North Kihei which are affected by chronic algae problems with, on the other hand, the experience of comparable, but unaffected, condominiums complexes in South Kihei (see map). This comparison is difficult for several reasons. First, while the North Kihei algae impact area is readily identified, not all condominium complexes within this area are equally affected throughout the year. Moreover, fluctuations per year are higher than assumed in the model. In short, we are measuring the relatively long-term economic effects of the algae problem in North Kihei. In particular, we concentrate on the difference in room rates, occupancy rates and property values.

Room rates: As part of the survey, data were collected on daily (transient) room rates at fifteen relatively large condominium properties that contained 745 units. Tariff information was obtained only from ocean front condominiums, since these properties are most likely to be affected by the algae problem. While data was collected on a variety of accommodation (e.g. studio, 1 bedroom, 2 bedroom, 3 bedroom etc.) not all properties offered all options. To simplify the analysis, a one-bedroom unit was used as the basis for comparison. The room rate used was the lowest published ('rack') rate in effect on May 1, 2002. Table 6.1 summarizes the room rate information.

Table 6.1 Comparison of daily rate for a one-bedroom condominium in Kihei, Maui

Property	Daily Rate in algae zone (US$/night)	Property	Daily Rate in non-algae zone (US$/night)
Menehune Shores	100	Maalea Surf Resort	205
Koa Lagoon	100	Royal Mauian	155
Kihei Beach Resort	135	Hale Pau Hana	160
Maui Sunset	99	Kihei Surfside	140
Maui Schooner	107	Mana Kai Maui	210
		Maui Oceanfront Inn	249
Average unit charge	*108*	*Average unit charge*	*186*

The room rate comparison shown in the above table clearly suggests a substantial difference in the room rates of condominiums in the "Algae zone'' of North Kihei from similar sized condominiums in the southern 'non-algae" zone. This differential is most evident in the comparison of two nearly identical 'sister' properties: the Menehune Shores and the Royal Mauian. These complexes are architecturally identical and units in each project have the same floor space and layout. The one bedroom units in the algae zone Menehune Shores rent for slightly less that two thirds the rates commanded by identical units in the Royal Mauian.

Occupancy rate: It is difficult to develop quantitative data on the occupancy rates of condominiums since condo owners (or their guests) are constantly taking up or leaving residence in their own units. Thus, the rental pool is constantly changing. Further, unlike hotels, the marketing of condominium rentals relies less on organized advertising or sales networks and more on word-of-mouth return business or information channels such as guidebooks or internet sites. The situation is further complicated, since unit owners in

a given complex may elect to self-rent their apartments as an alternative to having their units managed by a local rental management company. For example, one of the largest condominium complexes in the algae zone is the Maui Sunset. The property has over 216 units and rental marketing is handled by six agencies. In addition, numerous units are directly rented by owners.

Rental agents and owners who were interviewed from the "Algae zone" properties were unanimous in the belief that they suffered lower occupancy rates due to the algae nuisance. Interestingly, there seemed to be a common belief that vacancy rates were between 5-10% lower in the algae area than in similar properties in south Kihei. While such estimates are subjective and anecdotal, they do reflect the professional opinion of rental agents who manage units both inside and outside the algae problem area.

Private Property Values: The market value of a real estate unit is comprised of many tangible and intangible factors related both to the condition of the unit and to its location. The algae problem is a real factor in the price of condominium units in the North Kihei area. Everyone seems to accept that the algae problem makes North Kihei condo's less attractive and less valuable. There are two interrelated aspects to this property value impact. First, the algae nuisance makes units less attractive as residences. Second, the algae nuisance lowers property values by reducing the income producing capacity of the units as rentals (i.e. lower rental rates + lower occupancy).

To isolate the impact of this factor from other location-specific considerations a hedonic valuation exercise has to be conducted. However, this would require an extensive analysis, statistically linking a large number of real-estate transfers with different kinds of estate-specific information. Although the real estate prices have been retrieved from existing sources, the estate-specific information was not available. Therefore, the estimates in this survey are based on a simplified statistical analysis only. To develop an estimate of the impact of algae on property prices, tax records for 771 units in North and South Kihei were analyzed for the period 1998-2000. Table 6.2 presents the results of this rough analysis.

This comparison clearly shows a substantial difference that can at least partly be attributed to North Kihei's algae problem. However, there are so many variables potentially affecting property values that the estimates probably need some refinement. To eliminate differences in property values which might be associated with basic design, as well as apartment and complex amenities, we can compare sales prices for the sister properties of the Menehune Shores and Royal Mauian. These properties are, in terms of architecture, design, and amenities largely identical. The details of this comparison are presented in Table 6.3.

From this comparison of nearly identical properties, it is clear that one bedroom units in the algae zone (e.g. the Menehune Shores) were, over the three year study period, only ~43% as valuable as one bedroom units at the Royal Mauian. Clearly, the location of the two complexes had a very significant influence on the value of the units.

Table 6.2 Comparison of sales prices of comparable one-bedroom condo units in North and South Kihei over the period 1998-2000

Property zone	# units	Average condo price in 1998 (1000 US$)	Average condo price in 1999 (1000 US$)	Average condo price in 2000 (1000 US$)
Units in algae zone				
Menehune Shores	153	156	156	222
Koa Lagoon	42	172	No sales	218
Maui Sunset	225	128	139	160
Average price algae zone	--	152	148	200
Units in non-algae zone				
Kihei surfside	83	210	225	313
Hale Pau Maui	80	282	330	408
Kihei Beach	54	184	184	307
Royal Mauian	80	440	382	495
Average price non-algae zone	--	279	280	380
Average difference*	--	127 (119%)	132 (112%)	180 (111%)

* Algae versus Non-Algae Zone Condominiums

If we assume that the average price difference seen in the Royal Mauian-Menehune Shores comparison is representative of property differentials between the algae and non-algae areas, then condominiums owners in the Algae area are experiencing a substantial depreciation of the value of their properties. A simple extrapolation of the $249,000 / unit difference to all 754 'algae zone' units yields a depreciation value of nearly $188 million in lost property value. If we use a long-term interest rate of 5% / year to annualize this sum we have an annual loss of $9,387,300.

Table 6.3 Comparison of Sales Prices of 1 Bedroom Units in the Menehune Shores and the Royal Mauian Condominium Complexes for 1998-2000

Year	Menehune Shores		Royal Mauian		Difference
	# of Sales	Average price	# of Sales	Average price	% Difference in sales price
1998	6	156	3	440	182 %
1999	21	194	3	382	97 %
2000	12	222	8	495	123 %
Average 98-2000	194	190		439	131 %

Source: Hawaii State Tax Records

Private Clean-Up Costs

The major condominium properties in the algae zone have undertaken a privately funded beach clean-up program for a number of years. This program involves periodic (daily during peak seasons) collection of algae using traditional construction equipment. The collected algae is either bulldozed into shore berms along the beach front or stacked into piles in front of the Maui Sunset complex. The stacked algae is collected by Maui County trucks as the need arises and hauled to local composters for recycling. The algae clean-up and removal operation is mildly controversial insofar as the removal of beach

sand is an inevitable part of the current process. The Maui County Public Works Department is in the process of buying a beach clean-up machine that will minimize sand removal and algae handling. The beach clean up operation is undertaken by a private contractor at an annual cost to the condomiums of $55,000.

Changes in tax income

The state and county governments are significant stakeholders in the Kihei algae problem. The Maui County interest is directly related to property taxes. In turn, property taxes are linked to the real or imputed value of individual units. The State of Hawaii is a stakeholder in the algae problems as a consequence of its transient accommodation tax. This accommodation tax is currently assessed as 7.25% of the cost of lodging.[12] Thus, any difference between the property value or rental value of units within and outside the algae zone directly affects the tax revenue. Changes in tax revenue are generally not included in the change in the economic value of a coral reef ecosystem because it involves a value transfer rather than a change in the overall value. The change in tax revenues is therefore disregarded in the determination of the total economic value. However, from a stakeholder perspective, the issue of changes in tax revenues is important and therefore briefly addressed below.

Maui County Property Taxes: Again, we can return to the Menehune Shores - Royal Mauian comparison as a proxy for algae tax losses. Commonly, property taxes are assessed separately on 1) the value of the land and 2) the value of improvements to the land (in the present case, the value of individual condo units). Interestingly, land assessments for units at Menehune Shores are common for all one bedroom units while land assessments at the Royal Mauian reflect the difference in the size and location of individual units. Menehune Shores property tax rates are currently set at $42 /unit/ year while Royal Mauian property rates vary from $60 to $67/unit/year. On average, land assessment rates are about 33% higher at the Mauian than at Menehune Shores.

Not surprisingly, the assessed value of improvements reflects a similar pattern to the sales value parameter discussed above. The average "improvements" value for one bedroom units in the Royal Mauian in 2001 was $375,000 while the average improvement value at Menehune Shores was $147,000. In other words, "improvements" to units at Menehune Shores attracted only about 39% (147 / 375) of the tax that similar units at the Royal Mauian attracted.

In combination, the property and improvement assessments determine total property tax assessment per unit. Table 6.4 presents data on the seven condo complexes summarized in Table 6.2 (above). This data shows that the average 2001 property tax differential between the algae zone and South Kihei condominiums was $1339. This number suggests that unit owners in South Kihei paid 109% more for comparable 1-bedroom units than did owners in the North Kihei Algae zone. In other words, in 2001 South Kihei owners paid more than twice the property taxes that were assessed on North Kihei condominium owners.

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[12] Through a revenue sharing formula slightly over one seventh (~1%) of the accommodation tax finds it way back to Maui County.

Returning to the more precise comparison of the Royal Mauian and Menehune Shores, average 2001 tax collections for 1-bedroom units at Menehune Shores were $991 per unit. Annual taxes on comparable 1-bedroom units at the Royal Mauian averaged $2790 per unit. If we multiply the difference of $1799 by 147 (the number of units at Menehune Shores) we have an approximation for foregone county property tax revenue of $264,453 per year for this condominium complex only**.**

Extending this analysis to all of the 754 one- bedroom units in the algae zone is fairly speculative. A simple multiplication of the Menehune-Mauian differential (e.g. $1799) gives a foregone/ loss of property tax receipts of $1,356,446 per year. If we use the broader measure of Table 6.4, average property tax losses of $1339 per year equate to a total (for all 754 units in the algae zone) foregone property tax estimate of $1,009,606 per year. From this data we can conclude that lost property tax in the algae zone is between $1.0 to $1.3 million dollars per year.

Table 6.4   Property Tax Payments condo's in North and South Kihei (US$ per unit)

Properties in algae zone	Property Tax	Properties in non-algae zone	Property Tax
Menehune Shores	991	Kihei Surfside	2,403
Koa Lagoon	1,531	Hale Pau Maui	2,698
Maui Sunset	1,132	Kihei Beach	2,337
		Royal Mauian	2,790
Average Tax Algae Zone	*1,218*	*Average Tax Non-algae Zone*	*2,557*

State Losses in Accommodation Tax Receipts: Since the accommodation tax is assessed on the final accommodation bill, lost revenue for condo rental in the algae zone is a function of both the $77 per night room rate differential (see Table 6.1) and the lower occupancy rate (assumed here to be 5%). Unfortunately, there are no disaggregated publicly available tax records for the accommodation tax so we must make a number of assumptions regarding aggregate accommodation tax losses.

While considerable variation exists, there is evidence that units in the transient rental-pool encompass about 75% of the total units in the average condominium complex.[13] Commonly rental-pool units are currently occupied about 70-75% of the time they are in the pool (assume 250 revenue days per year). From these estimates we can make the following assumption of foregone accommodation tax revenues.

$$
\begin{array}{rl}
754 & \textit{Units in Algae Impacted Area} \\
x \quad .70 & \textit{In Rental Pool} \\
\hline
566 & \textit{Rental Units} \\
x \quad 250 & \textit{Revenue days/year/unit} \\
\hline
131950 & \textit{Total Revenue Days} \\
x \quad 1.05 & \textit{(5\%) Adjustment for Lower Occupancy} \\
\hline
138548 & \textit{Total Vacancy Adjusted Revenue Days} \\
x \ 78 & \textit{Differential Algae Zone and South Kihei prices} \\
\hline
\$10,806,705 & \textit{Lost rental revenue} \\
x \quad .0725 & \textit{Accommodation tax rate} \\
\hline
\mathbf{\$ \ 783,486} & \textit{Lost Accommodation taxes / year}
\end{array}
$$

[13] Based on personal communications with rental managers in 'algae zone' condominiums

Aggregating the Economic Data

Pulling together the various costs associated with condominiums in the algae zone is a reasonably straightforward task. The various elements in this calculation are presented in Table 6.5. Careful readers may question inclusion of both lost rental income and reduced property values in the aggregate estimate since there is relationship between these two parameters. Normal practice in financial analysis is to assume that 'property investments' reflect rental income in their sales prices. Under this assumption inclusion of both rental and sales losses would amount to double counting. However, the situation is complicated in the case of condominium units since it is unclear what fraction of unit owners consider their condo to be an 'investment'. This is especially true with units in the algae zone condominium complexes where investment returns have been modest to non-existent over the last decade. For some types of owners the primary motive is probably related more to use than to investment. These owners include both resident owners and owners of time-share units. For example, at the large Maui Sunset complex time-share owners account for ~ 20% of the units while ~10% of the units are permanently occupied by residents (thus, not subject to rental). Therefore both rental income and reduced property values are taken into account.

Table 6.5   Aggregated Cost Estimates

Cost Element	Estimate	Comment
Annual loss in rental income	$10,806,705	Rental differential of $78 / rental day
Annual loss in Property Values	$9,387,300	5% of $188 million
Clean up cost by Condominiums	$55,000	Paid by condominiums for beach clean-up
Clean up cost by County	$200,000	67% of county algae clean-up budget
Total Cost/Year	$20,449,005	

The above estimates are conservative because they are based on 1-bedroom units only. In fact, a substantial fraction of the units in each complex studied are two or three bedroom units. These larger units have higher tax, sales price and rental values and their inclusion would be likely to substantially increase differentials between algae and non-algae zone units.

The extent to which the location differential can be solely attributed to the algae problem is, of course, highly speculative. No doubt, other location factors (such as access to shopping and dining facilities and a better swimming beach) are significant factors in the economics of algae zone versus non-algae zone units. On the other hand, people buy oceanfront property primarily for the amenities that the ocean provides. If these amenities are significantly degraded by the presence of algae on the beach and in the water, common sense suggests that the location value of the condominium units at a particular site will be severely affected.

In estimating an imputed value of access to shopping and dining facilities it is interesting to make two comparisons. First, the traveling distances and times between North and South Maui are relatively short. The promotional literature for many of the North Maui condominiums state that they are only 5 minutes by car from the shopping and dining centers of area. Second, on a more practical level we can see from Table 6.1 that the daily rental rates (for one bedroom units) at the Maaleae Surf Resort are substantially

above rental rates at the non-algae zone units of South Kihei ($205/night versus an average of $187/ night).[14] Since the Maaleae Surf Resort complex is north of the algae zone hotels, it suffers from the same reduced access handicap as the algae zone condo units. Third, if we examine only the 5 non-algae complexes we note that the most expensive room rates are associated with the most southerly properties (e.g. Maui Beachfront Inn @ $249/night and Mana Kai Maui @ $210/night). While these properties are closer to the central (shopping and dining) area of Kihei than the North Kihei properties it is, in many cases, still necessary to travel by car.

Setting aside the substantial algae nuisance, assessing the basic difference in the quality of North and South Kihei beaches is a challenging analytical problem. For some uses, like beach walking or sunbathing, the differences are relatively minor. For other uses, such as swimming, South Kihei beaches are clearly superior. Ironically, it is possible that for a few uses, such as snorkeling or scuba diving, the North Kihei beaches might actually be preferable due to their higher coral abundance. On balance, the inferior beaches of North Kihei are probably a significant factor in the depressed property and rental values of the area. This natural disadvantage is substantially compounded by the algae problem that is chronic to the area. Without convincing evidence we have subjectively concluded that the "algae problem" in North Kihei is probably accountable for about one half of the economic differences between North and South Kihei condominium units. This would imply that the algae cause damage at the Kihei coast of about $30 million.

6.3 The model runs

As mentioned, the main goal of the Kihei Coast case study is to: (a) determine the value of the reef at the Kihei Coast, and to (b) evaluate the effectiveness of interventions that aim to reduce the nutrient outflow in the Kihei coastal waters in terms of net-benefits. To answer these questions, future developments will have to be taken into account. For this purpose the SCREEM model has been applied. The time frame of the evaluation is 50 years. Baseline developments have been made through literature searches and expert judgments. Moreover, ecological-economic interactions will impact both the state-of-the-reef indicator as well as the economic indicators.

When determining the value of coral reefs of Kihei Coast, the main question is what future conditions are taken into account. The economic value with a specific intervention, such as, for example, the upgrading of the sewage plant that reduces the nutrient levels in the coastal waters and thereby alleviates the algae problems, is most likely to be very different than the value without this intervention. Therefore we analyze values in this analysis under two distinct scenarios:

- *With nutrient reduction*: Several measures will be taken that are aimed to reduce the nutrient outflow to the Kihei waters. These include the upgrading of the Kihei sewage plant from secondary to tertiary treatment, and improved fertilizing practices in both the agricultural sector and the golf courses. Because current knowledge in this field is

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[14] A check of tax records suggest that recent sales prices for units in this complex are not significantly different from the sales prices of units in South Kihei.

still insufficient we will need to make a number of assumptions with regard to the effectiveness of these measures. This is explained below.

- *Without nutrient reduction*: No nutrient reducing measures will be taken. This implies that the current trends of algae blooms will continue to occur, leading to further coral reef destruction and continued algae nuisance at the Kihei beaches.

In the following sections, the ecological and economic effects under both scenarios are discussed in more detail.

Ecological effects

As explained in Chapter 4, reef building corals usually dominate and fleshy algae under conditions of low concentrations of nutrients and high grazing activity from fish and invertebrate species. The anthropogenic increase of nutrient levels in the surrounding waters of Kihei in the last decades has disrupted this ecological balance and caused the sudden bloom of algae. To simulate the possible effect of a reduction in nutrient levels, a simplified relationship between nutrient and coral cover has been applied in the ecological model. The ecological model assumes an excess concentration of nutrients 180% in 2000, which will remain unchanged in the "without nutrient reduction" scenario. As shown in Figure 6.3 the excess nutrient levels are assumed to decline to sustainable levels in approximately 26 years in the "with nutrient reduction" scenario.
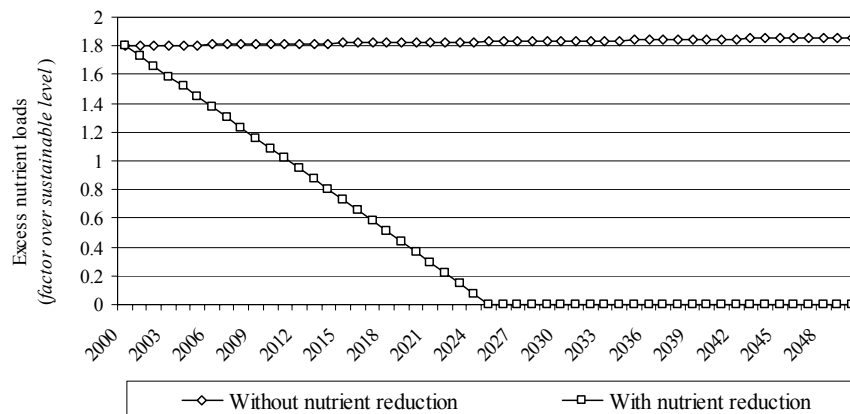
Figure 6.3   Assumed impact reduction of remediation measures on nutrient loads at the Kihei coast

Figure 6.4 shows the effect of nutrient reduction on the algae concentrations. Without efforts to reduce nutrient levels, the fleshy algae cover will continue to increase further from 20% in 2000 to 27% in 2050. This increase will take place at the cost of the coral cover. If the excess nutrient levels are successfully reduced, the algae cover will follow accordingly. Similar to the pattern of the excess nutrient decline the algae cover will reach sustainable levels of 10% around the year 2027. It should be realized that these ecological simulations are highly dependent on the assumptions and generalizations made by the authors. Although the character of the relationship between nutrients and algae, on the one hand, and between algae and coral, on the other hand, is well described in the literature, the exact intensity of these relationships is still uncertain. Therefore the outcomes of the ecological simulations are partly hypothetical.

Figure 6.4   Assumed impact of nutrient reduction on algae cover at the Kihei coast

Economic effects

The coral reefs at Kihei serve various purposes. Figure 6.5 shows the composition of the main benefits. The most important economic beneficiaries of the 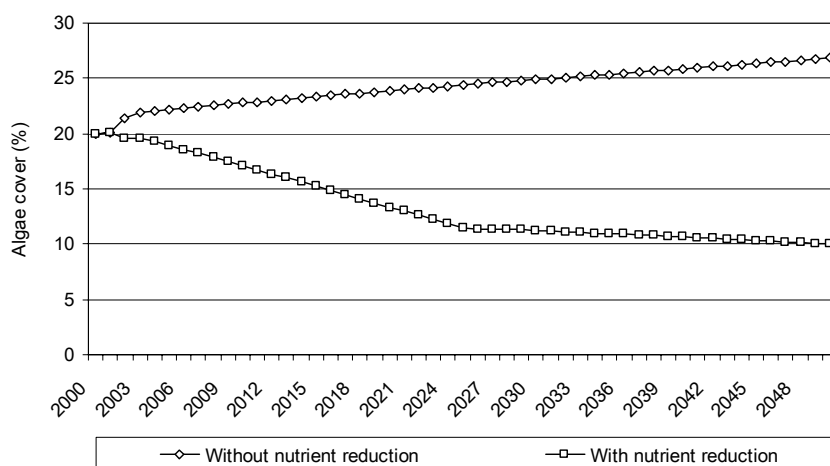coral reefs at Kihei Coats are the recreational and amenity values. The recreational benefits consist of mainly snorkelers that independently visit the reefs offshore (29%). Due to the lack of good dive sites, dive benefits are limited at Kihei. The majority of the economic benefits of the coral reefs consist of amenity benefits derived from the differences in property values of houses, hotels and condo's at healthy and unhealthy coral reefs (65%). This has been explained in the previous section.
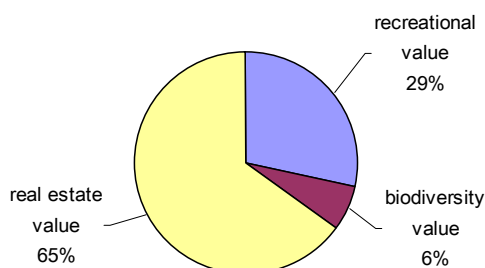
Figure 6.5   Allocation of main benefits if nutrient reductions are achieved

Figure 6.6 depicts the development of the annual benefits derived from the coral reefs for the scenarios with and without nutrient reduction. Not surprisingly, the annual benefits will further decline from $25 million to $9 million in a situation where the coral reef will gradually disappear and where algae blooms will continue to occur. In a situation where nutrients are successfully reduced, however, the annual benefits will eventually increase by almost $30 million. The majority of this increase is attributed to the growth in property values. In other words, if appropriate measures are taken, it will take approximately 50 years before the complete damage of the algae blooms caused at Kihei Coast so far is eliminated (see earlier section). Due to the delay between the time of the interventions (e.g. sewage upgrade, fertilizer improvement) and the actual reduction of the nutrient levels at the Kihei waters, the annual benefits will inevitably decline another 10 to 15 years before the reef will recover and the ecological effect have materialized in economic benefits.

*Figure 6.6   Development of benefits from the coral reefs with and without the reduction
of nutrients levels at the Kihei coast*

To get an idea of how the benefits of action (e.g. the shaded area between the two curves
in Figure 6.6) compare to the cost of the required intervention, the cost of upgrading the
sewage plant at Kihei from secondary to tertiary has been estimated. We do not claim
that this would include all the costs required to solve the algae problem at Kihei but it
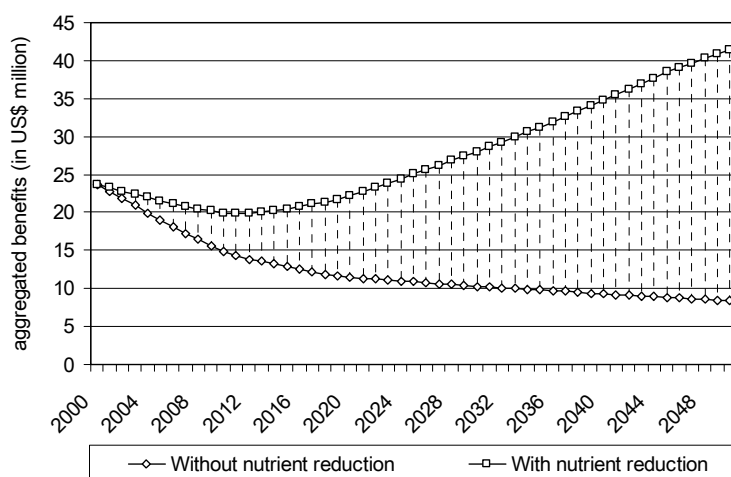gives us at least some rough idea of the proportion between benefits and costs.

Beginning in 1995 Maui County began a long term upgrading program for its sewerage
plants at Lahaina and Kihei. This plan was designed to upgrade treatment from
secondary to tertiary levels and explicitly recognized the nutrient and algae problem. As
part of this plan the county commissioned the Brown and Caldwell consulting company
to study "Rate and Fee Alternatives for Reclaimed Water Service". This study examined
the costs of upgrading sewerage effluents to levels that would be suitable for selling
reclaimed water to a number of identified users. While the study focused on pricing
options its analysis contained fairly detailed information on both capital and operating
costs. Further, since the study was designed to examine delivered costs (to users), it
provides a convenient estimate of what it might cost to address the "injection problem"
uncertainty by reticulating recycled effluent to major water consumers.

The Brown and Caldwell Study identified 6 potential users in the South Maui area.
Capital costs to serve these users were estimated to be $13.288 million and annual
operating costs were estimated at $517,000 /year. On a constant ('95) dollar basis the
estimated annual costs for the 8 million gallon/day reclaimed water scheme is slightly
over $2.3 million per year.

Figure 6.7 shows how the costs compare to the benefits of the nutrient reduction scheme
at various discount rates. For all discount rates, the benefit cost ratio exceeds 1, implying
the cost effectiveness of the intervention. Two remarks are made with this conclusion.
First, as mentioned, sewage upgrading is only part of the problem and may therefore not
be sufficient to solve the algae problem. The costs are therefore most likely higher than
assumed in this analysis. Second, only the benefits are taken into account that relate to
coral reefs directly. In reality, a number of site benefits are achieved, such as health
effects and water savings, that have not been taken into account in this study and that are
often the sole reason to upgrade sewage systems. The benefits considered are therefore a
significant underestimation of the real societal benefits that occur.
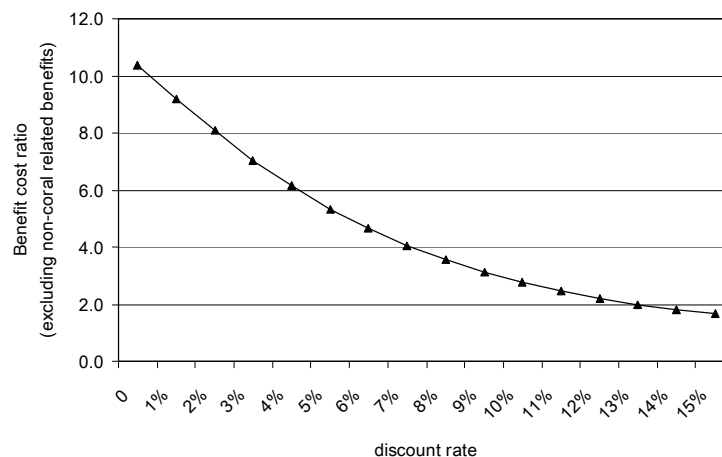
Figure 6.7 Benefit cost ratio of nutrient reduction at the Kihei coast, assuming sewage upgrading can achieve the complete required nutrient reduction.

6.4 Lessons learned

The Kihei Coast study is incapable of revealing the full picture of the associated costs and benefits of the algae problem. To address these issues appropriately more geological, hydrological, ecological, and economic information is required. This can only be achieved with the help of a multidisciplinary team and with more extensive funding. Despite these handicaps, an attempt was made to retrieve a ballpark figure of the economic values related to the coral reefs and the algae problems, and to compare these with a rough estimate of the upgrading costs of the sewage plant in Kihei. Several conclusions have been drawn:

- The losses of real estate value and hotel business are the main effects of the algae problem at Kihei.
- It seems that the costs of reducing nutrient concentrations are smaller than the loss of benefits of the algae problem.

7. Overfishing at the Kona coast, Big Island

The island of Hawaii, often referred to as Big Island, is nearly twice the size of all other Hawaiian islands combined. The entire sunny western coast of the island is called the Kona coast. The Big Island is formed by volcanoes. These extend downward to the ocean floor, miles below the surface. The corals along the Kona shore have not formed reef-structures and are therefore not fringing reefs but coral communities. The coastal area is characterized by steep

Figure 7.1   Aquarium fisheries at Kona Coast

nearshore drop-offs with lava tubes and caves. The Coral Reef Assessment and Monitoring Program (CRAMP) has conducted benthic surveys in several locations along the Kona coast. Though the reefs were often in healthy state, coral cover was low at 0-10% for all sites at a level of 3 meters and at 0-20% for all sites at a level of 10 meters (Jokiel et al., (2001).

7.1 Local conditions

The coral reefs along the Kona coast have a number of benefits to humans, including fisheries and recreational and tourist activities such as snorkeling, diving and dive-boat operations. Also, there is a strong cultural subsistence use by local Hawaiians. Given the benthic structure, coral reefs in Kona coast have little coastal protection function. At the same time, part of the property value of beachfront houses and hotels can be attributed to the presence of coral reefs. Also, there is a research value attached to the Kona reefs.

Concern over the effects of aquarium collecting on reef fish populations began in the early 1970s. Conflicts between the local population and the aquarium fishermen were on the rise in the 1990. The tourism industry claimed that the decline in biodiversity in the area was caused by the aquarium fish industry and complained that this reflected badly on tourism. To resolve these conflicts, Fish Replenishment Areas (FRAs) were established where aquarium fish collecting is prohibited. The FRAs make up 32.5% of the total nearshore habitat along the Kona coast ((see Figure 7.2). The establishment of the FRAs will be discussed below in qualitative terms. However, no benefit-cost analysis of the establishment of FRAs will be carried out here. The reason is that implementation has only started in the year 2000: to recent to draw any definitive conclusions on the impact and effectiveness of the FRAs.
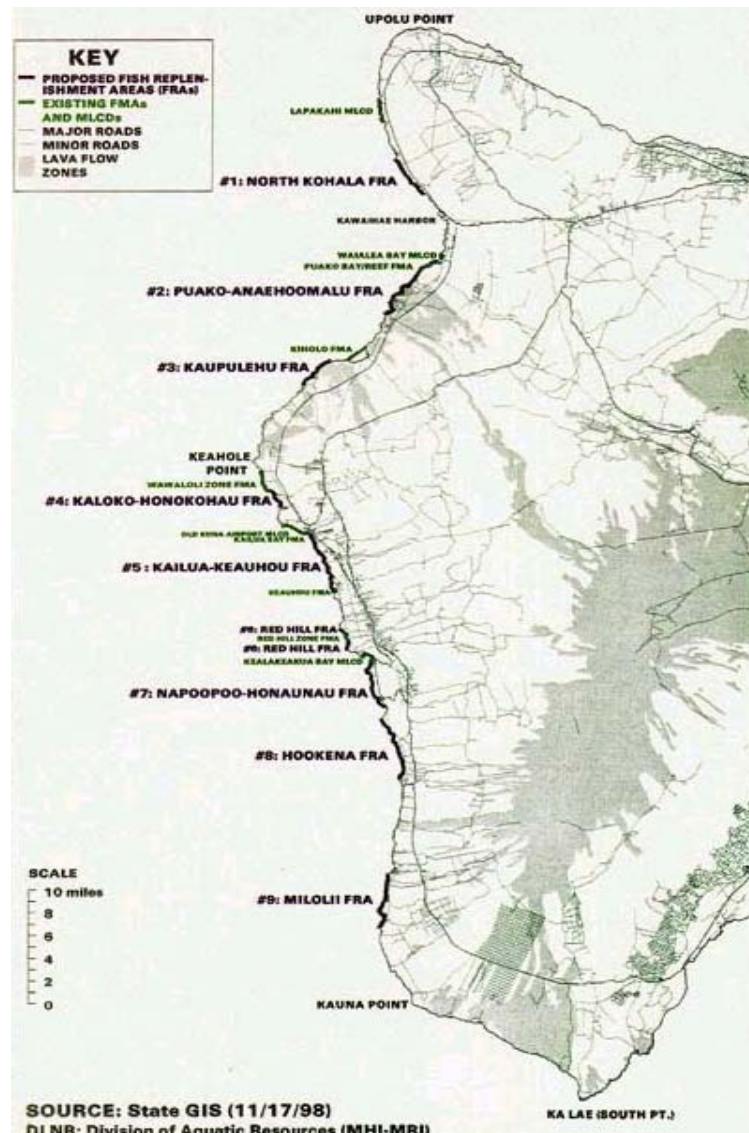
Figure 7.2   West Hawaii proposed FRAs

7.2 The survey: Aquarium fish industry in West Hawaii

After re-evaluating the industry value, our study finds that the aquarium fish industry, though small in terms of fishermen involved, is currently one of the largest inshore fisheries in the State of Hawaii. Despite its economic importance and potential environmental impact, the industry has been largely unregulated in Hawaii. Published information on the industry is primarily based on data from catch reports that aquarium collectors are required to file by law with the Hawaiian Division of Aquatic Resources (DAR). Annual summaries were published by DAR until 1994, and a five year summary of fiscal years 1995–1999 is given in Miyasaka (2000). The last in-depth socio-economic study of the industry was carried out by van Poollen and Obara (1984). This case study presents a re-evaluation of the socio-economic characteristics of the industry based on interviews of aquarium collectors.

The case study focuses on the West coast of the Big Island of Hawaii, which has been the most important catch area for ornamental fish in the state of Hawaii since 1994. Over

80% of collectors and wholesalers live in the Kailua–Kona region. Over the last 5 years, the Kona fishery has consistently been the most important aquarium fish catch area in Hawaii. Between fiscal year 1995 and 1999, the Kona fishery catch made up between 49% and 67% (an average of 58%) of the state-wide total aquarium catch in Hawaii.

Collection of Aquarium Fish in the state of Hawaii requires a permit issued by the Division of Aquatic Resources (DAR). Past studies indicate that although non-commercial licenses in Hawaii may be substantial in numbers issued, this does not translate into relevant catch amounts (e.g. van Poolen & Obara 1984 determined non-commercial at 1 – 2 % of total catch). This study therefore concentrates on commercial permit holders. 52 commercial collecting permits were issued on the Big Island at the time this study was conducted,. but only an estimated 22 collectors were active. Of these, 16 were independent contractors and 6 were collectors who also worked as wholesalers. Besides, there are two exclusive wholesalers, bringing the total number of wholesalers to eight.

The main fish collection method of all collectors interviewed is the use of barrier nets (also called fence nets). Accessories to this catch method are scoop nets, long sticks called "tickle sticks" and catch buckets. Fish are either herded into the net by one or several scuba-divers using tickle sticks, or they are chased out of their territory, then the net is set, and the returning fish get caught in the almost invisible net. The mesh size is usually not more than a ¾ inch.

Mortality rates of aquarium fish are low and have gone down considerably since the last survey in 1984. Currently, mortality rates from collection to wholesaler are estimated at 0 to 1 percent. In the wholesalers' tanks, mortality rates range from close to 0% up to 2% During shipment, rates range from 0.75% to 2%. This gives a current total of between 1% and 5%, down from a range of 5% to 8% in early 1980s (van Poolen and Obara, 1984; estimates of wholesalers and collectors, own study). A reason for this decrease may be the improved quality of wholesalers' holding facilities. Decreases in mortality during shipping could be accredited to better flight connections and better know-how. The use of chemicals (e.g. cyanide) for collections is forbidden in Hawaii. As noted by van Poolen and Obara (1984), mortality rates of aquarium fisheries using chemicals are several times higher than those using nets.

Kona aquarium fishermen target mainly the following four top-species of fish: Yellow Tang (lau´ipala; *Zebrasoma flavescens*), Goldring Surgeonfish (kole; *Ctenochaetus strigosus*), Achilles Tang (paku´iku´i, *Acanthurus achilles*) and Naso Tang or Orangespine unicornfish (umaumalei; *Naso lituratus*). The total range of species caught is much larger, and it should be noted that low catch of rare species may have as significant ecological consequences as high catch of an abundant species. Other species caught are for example Moorish Idol (*Zanclus cornutus*), Chevron Tang (*Ctenochaetus hawaiiensis*), Goldrim Surgeon (*Acanthurus nigricans*) and Longnose Butterflyfish (*Forcipiger longirostris*). Yellow Tang is the bread-and-butter of the aquarium trade, with 77.8% of the total catch numbers. The "Big Four" together make up, on average, over 90% of the catch. In terms of value, the four species contribute 87.2% to the total. The catch composition is given in Figure 7.3.
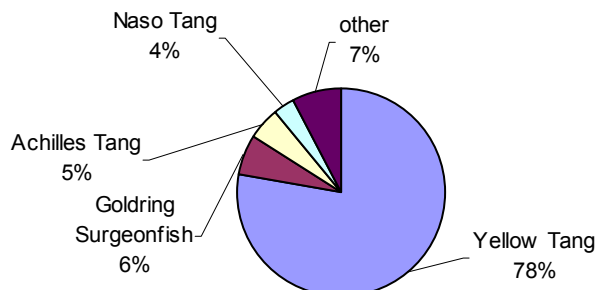
Figure 7.3 Average relative importance of commonly caught species in the state of Hawaii by count (data from Miyasaka 2000)

Virtually all fish collected on the Big Island pass through one of the eight existing wholesale businesses. Only a very small percentage of these fish are sold on the Big Island, the rest are shipped from the island (98%). Customers of wholesalers are found on Oahu, the mainland US, Europe and Asia. Almost all shipments go to Oahu first, because of uneconomic freight rates from Kona International Airport, concern about delays that increase fish mortality, and problems with agricultural inspections for international shipments. On Oahu, distributors sell fishes either to local retailers, or to customers on the mainland and in other countries. Eventually, over 90% of Big Island caught fishes are exported out of State (data obtained through own surveys).

In terms of price the existing market structure leads to the existence of two market prices, one paid to independent contractors by wholesalers and the other paid to wholesalers by their customers. It was found that the wholesaler price is on average more than twice as high as the divers price. The price development for the "Big Four" is given in Figure 7.4.
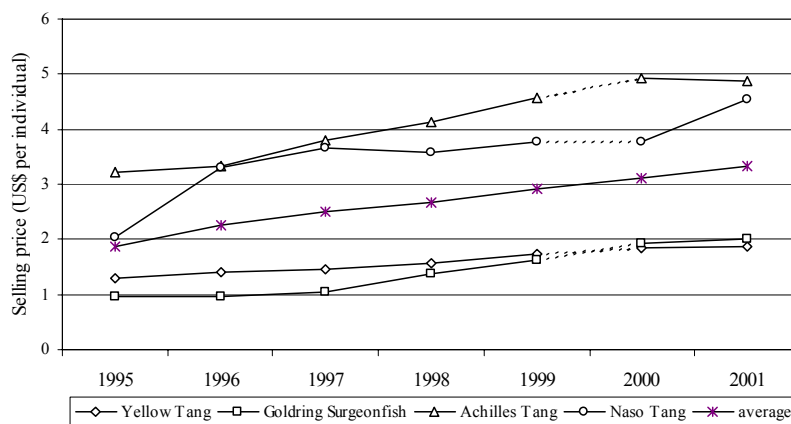
Figure 7.4 Price development of the four most important species in the state of Hawaii aquarium fishery (from Miyasaka 2000, DAR unpublished data and own findings); data for 2000 are missing.

Based on our own surveys, profit margins were estimated for independent contractors ranging from 42.5% to 67.5%. The average profit margin is estimated at 60% of gross value of fish sold to wholesalers. For wholesalers, detailed numbers from one business showed a profit margin of 22.2% (after taxes before social security payments). Other wholesalers estimated the margin for their business. The range of estimates was 20% to 30% of gross sales. The average was a profit margin of 25% of gross sales.

As mentioned above, DAR catch report summaries contain value estimates for the catch from important catch areas in the state. Since 1995 no estimate has been published, although state law requires a monthly count of each individual species to be reported. Below, our own value estimates are presented for fiscal year 2002 for the estimated 22 collectors and eight wholesalers in the industry in Kona (see Table 7.6). For the Big Island industry, this study estimates a gross value of fish sold by the independent contractor segment of $633,000 and profits of $380,000. The wholesale segment generates a gross value of $1,209,000 and profits of $302,000. The industry gross sales are estimated at $1,842,000, industry profits are $682,000 (Table 5). This estimate probably represents a minimum industry value, considering reports of underreporting and non-filing of catch reports.

Table 7.6   Estimated Gross value and profits of the West Hawaii aquarium fisheries

Industry Segment	Gross value	Profit
Independent contractors	$ 633,000	$ 380,000
Wholesalers	$1,209,000	$ 302,000
Total	$1,842,000	$ 682,000

Given the fraction of 58% of West Hawaii aquarium fisheries out of the total aquarium fisheries in the State of Hawaii, this study estimates a gross value of animals sold by the independent contractor segment of US$1,1 million and profits of US$ 0.7 million. The wholesale segment generates a gross value of US$ 2.1 million and profits of US$ 0.5 million. The industry gross sales are estimated at US$ 3.2 million and industry profits are US$ 1.2 million. Value added is equated with industry profits as no labor costs have been included in the cost figures. It is interesting to note that these figures are considerably higher than the official DAR industry summary for 1995 (Miyasaka 1997), which estimates the industry value at US$ 844,843. This figure and previous official estimates were used as basis of a number of publications, e.g. Wood (2001), that mention a Hawaii industry export value between $800,000 and $900,000 for the late 1990s. While a direct comparison of this and previous estimates is not possible because these estimates refer to different years, it appears that previous estimates were underestimating the industry value. The reason may be that previous reports did not take the structure of the Hawaiian market into account sufficiently and as a consequence used export ratios and price estimates that were too low.

With the value estimate presented above, gross income and profit per active contractor/wholesaler can also be calculated. An independent contractor on the Big Island would, on average, have a gross income of US$ 28,773 and a profit of US$ 17,273, while the average gross income per wholesaler would be US$ 151,125 and a profit US$ 37,750 (Table 7.7). Observations from the field of a yearly income $36,000 and $42,000 for two independent contractors collecting fulltime again indicate that the study estimate is likely to be lower than the true value (own study).

Table 7.7   Gross income and profit per person, Big Island industry

	Independent contractor	Wholesaler
Gross income/Person ($)	28,773	151,125
Profit/person ($)	17,273	37,750

CPUE data, which collectors submit to DAR, are somewhat surprising. For the beginning of the 1980s, van Poolen and Obara (1984) found a CPUE of 13 animals per hour. In 1991, CPUE was 19 animals per hour, and until 1999 it increased to 62 animals per hour (see Figure 7.5). Collectors appear to have become more professional since 1984 (including use of advanced boats, overnight trips, life wells that allow storing of fish, use of scooters and nitrox diving by some collectors), which may account for part of the increase in CPUE. DAR - data also suggest that collections of rare, harder to catch, but more valuable species have decreased in favor of easier to catch species, especially Yellow Tang (own analysis). Nonetheless, a more than quadrupling of CPUE in less than 20 years would be enormous considering that no revolution in collection techniques has taken place. It is questionable that currently available CPUE information allows insight into fish populations without further analysis. In particular, changes in target species over time, possible inaccuracy of catch reports and lumping in of invertebrate catches in catch reports should be addressed.
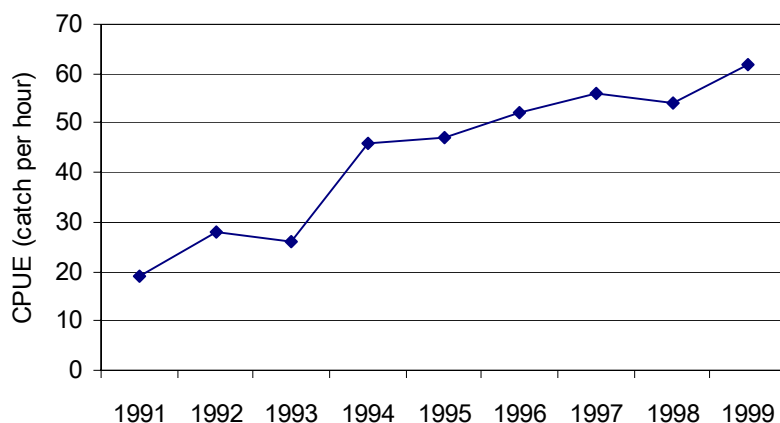
Figure 7.5   Catch per unit effort along Kona over time 1991-1999.

Regarding maximum sustainable yield (MSY) of ornamental fish species, no conclusive estimates currently exist for the aquarium fish fishery in Hawaii. In fact, studies have produced very contradictory results (see Woods, 2001 for a summary). In the eyes of experts, it is unlikely that aquarium fish populations of the four most commonly caught species will suddenly crash, considering that a relatively constant number of collectors has generated a stable catch for about 10 years on the Big Island (personal communication Dr. Walsh, DAR). This does not say that the catch is at maximum sustainable at present level or not. Nonetheless, it appears likely that in the near future mainly socio-economic factors will determine catch numbers. Another issue is the current age of collectors and wholesalers. Several key industry collectors and wholesalers are in their 50s and plan to go on for only 3-4 more years. It will be interesting to see if new collectors step in. Also, law mandates a review process of the FRAs for 2005. It is likely that this process will have implications for fisheries.

7.3 The economic value of the Kona Coast

In the Kona case study, no attempt was made to select a management scenario for a benefit-cost analysis, mainly because the FRAs were introduced recently and no credible long-term trends could be detected yet. Therefore, only the components of the annual benefits used for the estimation of the Total Economic Value for Kona are presented below. These components are recreational benefits, biodiversity benefits, non-use benefits, fishery benefits and annualized amenity/property values. First, recreational benefits are presented in Table 8. These show the estimated number of divers and snorkelers (both resident and visitors) and the value added per person for each of these four groups. These value added figures are explained in considerable detail in Chapter 7. They consist of a value added of direct and indirect expenditures, together with the estimated consumer surplus and multiplier effect. The resulting annual value added is slightly above $8 million.

Table 8   Recreational benefits per year at the Kona coast (2001)

Recreational values	# persons	Value added	Total value added
Residents – Divers	4,200	$29	$122,346
Residents - Snorkelers	28,000	$29	$815,640
Visitor – Divers	109,159	$28	$3,076,328
Visitor – Snorkels	85,833	$47	$4,042,389
Total			$8,056,703

The annual biodiversity benefits for the Kona coast consist of all reef-associated research expenditures as well as residents non-use benefits. A full list of research expenditures in Hawaii with a annual level of $10.4 million is presented in Chapter 7. Of these expenditures a small proportion is Kona coast-related, estimated at $ 783,000.

Table 9   Annual non-use benefits at the Kona coast (2001)

Non-use value	# households	WTP	Total value
Residents	33500	$10	$335,000
Other residents	366667	$1	$366,667
Visitors	1093524	$3	$2,865,033
Total			$3,566,700

Non-use values are essentially values attributed to the very existence of coral reefs by those people who do not visit the reefs. These people are Hawaiians and visitors who do not go diving or snorkeling but who derive some benefit from the knowledge that the reef exists and are willing to pay a certain amount of money to maintain the reef in its current state. Table 9 shows the number of 'non-users' and their respective willingness-to-pay. This value is further explained in Chapter 8. For Kona coast, this annual non-use benefits are $3,566,700. This brings the total biodiversity benefits at $ 4.35 million per year.

The fishery benefits along Kona coast have been discussed in detail above (Table 7.6). The collectors and wholesalers together have a total value added per year of $ 682,000. Note that we have excluded recreational fisheries and subsistence fisheries for other

target species than ornamental fish. Hence, the fishery benefits presented here are a 'lower bound' estimate of total fishery benefits in Kona.

The final benefit considered here are the amenity/property benefits of condos, residential houses and hotels. The annualized value of property within one block of the ocean in the Kailua-Kona area is estimated at $2.1 billion, based on real-estate prices. We have taken a small share of the property value to be determined by the state of coral reefs: 0.3% for condos, 0.15 for residential houses and 0.23% for hotels (see Table 10). An explanation of these numbers is given in Chapter 7 below. This gives a total annualized reef-related value of $4.57 million.

Table 10   Amenity/Property value at the Kona Coast (2001)

	Property value Kona (in million US$)	Reef-related value (in million US$)	Relative share of total value
Condo	385	1.16	0.30%
Residential	646	0.97	0.15%
Hotels	1,087	2.45	0.23%
Total	2,118	4.57	

Comparing the four annual benefits, it is obvious that the recreational value is the highest at 45 percent of total benefits (Figure 7.6). Annualized amenity/property values and the biodiversity benefits are each roughly a quarter of total benefits. Finally, fishery benefits are estimated at 4 percent. The total annual benefits are estimated at $17.7 million from the four reef-related goods and services discussed above.
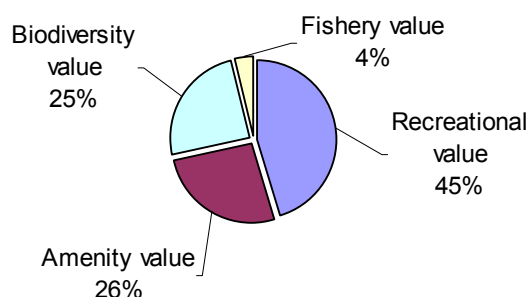
Figure 7.6   Composition of the benefits at Kona Coast, Big Island

7.4 Fish Replenishment Areas (FRAs)

Public pressure resulting from perceptions that fish populations were declining was a main reason why 32.5% of the Kona coast was closed in 2000 to aquarium collections as Fish Replenishment Areas (FRAs). Since then, tensions have declined and the public accepts present catch effort. A strong increase in numbers of collectors would likely trigger new protests. These FRAs have limited potential catch areas, but no regulations were put in place to manage open areas. DAR, conservation agencies and many collectors agree that a limited entry fishery would be desirable. Limited entry would also restrict the scope of the fishery.

The case for Fish Replenishment Areas and other forms of reserves and protected areas in the Main Hawaiian islands is strong given the high level of reef fish exploitation

(Friedlander and DeMaritini; 2002). This is evidenced by high levels of herbivores in reef fish assemblages and large numbers of sexually immature fish at landing sites (Birkeland and Friedlander, 2002). Table 7.11 gives fish stocks in selected shoreline areas with different forms of fisheries management. As can be seen, Hanauma Bay has the highest standing stock of the areas presented here with 1.65 mT/ha. This area was established as marine life conservation district in 1967. Puako Bay along Kona coast on Big Island is part of the newly established West Hawaii Regional Fishery Management Area, where aquarium fish collection is forbidden. Puako Bay is one of the in total nine FRA in this management area.

Table 7.11 Fish Populations around selected shoreline areas: number of fish species and standing stock

Area	Island	management regime	species	mT/ha
Hanauma Bay – inshore	Oahu	Marine Life Conservation District	59	1.65
Waikiki MLCDs	Oahu	Marine Life Conservation District	42	0.28
Molokini shoal	Maui	Marine Life Conservation District	58	0.70
Puako Bay and Pualo Reef	Hawai'i	Fisheries Management Area	34	0.38

Source: DAR (2001), Statewide Marine Research and Surveys, Survey of Fish and Habitat, July 1, 2000 to June 30, 2001. Numbers recalculated in metric system.

Predictions as to the future catch of ornamental fish along the Kona coast seem nearly impossible. It is important to understand that the current situation is transient. In 2000, the FRAs were implemented. As an immediate consequence, the available catch areas got considerably smaller. The number of collectors has remained almost the same since 2000, so that areas that remain open to collections are more heavily collected than before (DAR, unpublished data and our own findings). On the other hand, biologists hope that FRAs will eventually benefit the fishery through enhanced recruitment and possibly spillover and counterbalance higher collection intensities per area and. There are indications that in the next three to four years, the Big Island fishery will generate a similar catch as in 2002. Value estimations for FY2001/02 can therefore be projected into the near future, with a possible increase in value due to a current upward trend in price.

8. Total economic value for coral reefs in Hawaii

One of the objectives of this study is to determine the overall value of the coral reefs of Hawaii. This requires a somewhat different approach than the methodology applied in the earlier case studies. The level of variation in ecological (i.e. type of reef, forms of threats) and economic (i.e. type of benefits, variations in interventions) indicators is so vast that a "with" and "without" evaluation over time would not be analytically feasible. Especially the mutual interaction between the various modules (i.e. ecological, tourism, fisheries, amenity) is very complex from a Hawaiian wide perspective. Therefore, we estimate the various benefits related to coral reef individually (tourism, fisheries, research, etc.). These individual benefits are subsequently aggregated to a total economic value for the coral reefs for Hawaii.

8.1 Recreational value

To calculate the recreational benefits of the Hawaiian reefs, several steps have been taken. First, we identify the size of the recreational users of the coral reefs of Hawaii. Obviously, not all visitors go snorkeling or diving. As mentioned in the Hanauma Bay study, the survey revealed that the most active snorkelers/divers were the Europeans of whom 95% went snorkeling or diving. The least active user groups were the Japanese of whom only 60% actually put their head in the water. Combining this information with the overall visitor numbers, a rough estimation can be made of the number of snorkel and diving trips conducted in Hawaii (see Table 8.1). To verify whether this number is within reasonable limits of the population of clients of the diving and snorkeling industry, a comparison was made with the number of dives reported by the industry. As explained in the Appendix, these two numbers match rather well.

Table 8.1   Estimated number of dives and snorkeling trips in Hawaii in 2001

Type of visitor	Number of snorkeling trips [a]	Number of dives
Residents	1,236,642	370,993
US West	5,568,548	170,772
US East	3,861,933	118,435
Japan	1,553,028	135,029
Canada	609,658	18,697
Europe	443,461	13,600
Other …	1,371,687	42,066
Total	*14,644,957*	*869,590*

[a] Includes both organized and unorganized snorkeling experiences

The next step in calculating the recreational value of Hawaiian reefs involves a determination of the monetary value attributed to each marine activity. We have taken into account four categories (see Table 8.2).

1. The welfare gain of the visitors as reflected in their expressed consumer surplus. In other words, the amount the visitors would have been willing to pay in addition to the actual payment to enjoy the Hawaiian reefs experience.

2. The actual expenditure directly related to snorkeling or diving experience. This includes entry fee, hiring of mask and fins, bus fare etc. We assume that only 25% of these expenditures can be considered as value added.
3. The expenditure indirectly related to the marine experience such as hotel costs and travel costs. DBEDT (2001) reports that marine activities such as diving and snorkeling form 18% of the total motivation of visitors to come to Hawaii. Again we assume that for the hotel expenditures, only 25% can be considered as value added for the Hawaiian economy. For the ticket costs of the air fair this value added rate is only assumed to be 2%.
4. The multiplier effect of 1.25 for the Hawaiian economy (DBEDT, 2001).

The current annual recreational value of the coral reefs of the Hawaiian reefs for snorkelers and divers is estimated to be \$281 million and \$44 million, respectively. Although the direct expenditure per diver is much larger than the direct expenditures of snorkelers, the overall value related to the latter group is much larger due to their large numbers.

Table 8.2   Recreational value of coral reefs in Hawaii in 2001 (in US$)

	Consumer surplus	Value added of direct expenditure	Value added of indirect expenditure	Multiplier effect	Total value added
Snorkelers					
Residents	10,053,899	2,318,704	-	579,676	12,952,279
US West	47,833,826	20,882,055	23,136,504	11,004,640	102,857,025
US East	33,174,006	14,482,250	20,450,444	8,733,174	76,839,874
Japan	13,340,508	5,823,854	2,189,058	2,003,228	23,356,648
Canada	5,236,964	2,286,218	3,587,133	1,468,338	12,578,653
Europe	3,809,326	1,662,977	2,246,766	977,436	8,696,505
Other …	11,782,791	5,143,826	6,794,101	2,984,482	26,705,200
Subtotal	*125,231,322*	*52,599,883*	*58,404,007*	*27,750,973*	*263,986,183*
Divers					
Residents	3,450,231	5,137,088	-	1,284,272	9,871,591
US West	1,588,179	3,152,878	3,545,777	1,674,664	9,961,498
US East	1,101,444	2,186,603	3,134,126	1,330,182	7,752,355
Japan	1,255,768	2,492,969	2,710,742	1,300,928	7,760,407
Canada	173,878	345,185	549,745	223,733	1,292,541
Europe	126,477	251,085	344,327	148,853	870,742
Other …	391,212	776,641	1,041,228	454,467	2,663,548
Subtotal	*8,087,190*	*14,342,448*	*11,325,946*	*6,417,099*	*40,172,682*
Total recreational value					
Residents	13,504,130	7,455,792	-	1,863,948	22,823,870
US West	49,422,006	24,034,932	26,682,281	12,679,303	112,818,522
US East	34,275,450	16,668,853	23,584,570	10,063,356	84,592,229
Japan	14,596,276	8,316,823	4,899,800	3,304,156	31,117,055
Canada	5,410,842	2,631,403	4,136,878	1,692,070	13,871,193
Europe	3,935,804	1,914,062	2,591,094	1,126,289	9,567,249
Other …	12,174,003	5,920,467	7,835,329	3,438,949	29,368,748
Total	*133,318,511*	*66,942,331*	*69,729,953*	*34,168,071*	*304,158,866*

8.2 Amenity value

For various reasons, properties that are close to a healthy marine system are more valuable than comparable properties that are not. The view of a clean beach and a healthy coral reef are perceived as a benefit to those that can enjoy it every day. Also, the presence of a healthy reef is more likely to prevent beach erosion and therefore indirectly serves as a form of coastal protection. Therefore, beachfront houses at a beautiful coast with clean beaches and healthy coral reefs generally sell for a significantly higher price. The same holds for condos and hotel rooms at healthy marine systems that generally command higher room and occupancy rates.

To accurately capture these value differences is a complex exercise that requires an enormous amount of information. As explained in Chapter 2, the proper way to value these so-called amenity values is to conduct an elaborate hedonic pricing method. Due to the limited means at our disposal, this is beyond the scope of this study. Therefore an alternative and simplified approach has been applied. First, on the basis of interviews with real estate agents, expert judgments were retrieved that express a certain proportion of the beach-front level of residential, condo and hotel property values. Next, the overall value of these three categories has been estimated. Due to the different sources and formats of data, different methods of data collection and estimation have been followed for residential[15], condo[16] and hotel[17] properties.

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[15] For residential property Values (1) from real estate and tax records determined the mean value of oceanfront residences by sub-area. Sub-areas defined using tax map key information. Real estate value was slightly different in the Oahu and W. Hawaii Surveys. For Oahu real estate 'asking price' information was used. To compensate for differences between 'asking' and 'actual' sales prices an arbitrary factor of 90% was applied to the residential asking price. For W. Hawaii actual sales prices for a one year period (mid 2001-2002) were used in the study. (2) we calculated mean value of all oceanfront properties in area and sub-areas; (3) From Tax maps we estimated the relationship between tax assessment of ocean from property and aggregate tax assessment of properties within one block of ocean. (An attempt was made to select a indicate sample as close to valued oceanfront property as possible) A ratio was created for each sub-area that related tax assessment of oceanfront to aggregate tax assessment for properties within a block distance from the ocean. This number varied from 2.5 to 4 depending on the sub-area. (4) We multiplied the mean oceanfront value by the number of ocean front properties to determine the aggregate value of ocean front property by sub-area. (5) We multiplied the aggregate ocean front value by the "1 block factor"; (6) and summed all sub-areas.

[16] For condominiums we (1) determined the the mean value of units in each condominium complex from real estate and tax records; and (2) multiplied the mean value by the number of unit is complex.

[17] For Hotels (1) from State Survey (DBEDT "Visitor Plant Inventory") determined the number of hotel rooms in area or region; (2) from State Survey ("Trends in the Hotel Industry"- Hawaii PKF consulting service) determine the Average daily rate by area for the period January 2002-May 2002. (3) and multiplied the number of hotel rooms by average daily rate to determine aggregate value of hotel inventory times 1000. This rule of thumb methodology is well established in the hotel industry as a valuation measure. It has been shown to provide estimates that are within 2% of eight other valuation methods.

Most efforts at calculating the coastal property value were focused at Oahu and Big Island. At Oahu the study considered: (1) 1,500 condo units in waterfront complexes; (2) 85 current real estate listings for residential properties as of 15 August; (3) 1,719 waterfront properties in 15 sub-areas of Oahu; and (4) 27,665 hotel rooms in Waikiki and 3,881 hotel rooms outside of Waikiki. At Big Island, specifically in the Kona/Kohala region we considered (1) 368 real estate sales for 2001-02 representing 1650 condo units in waterfront complexes; and (2) 2566 hotel rooms in Kailua-Kona and 3427 hotel rooms in Kohala.

To transfer the property values for Oahu and Big Island to Maui and Kauai we used resident numbers in 2001 for residential properties and visitor numbers in 2001 for hotel and condo property values. Table 8.3 shows the property values within 100 meters of coast of the Main Hawaiian island in 2001. Not surprisingly, Oahu outweighs the other islands. Both property value and population density is much higher at this island.

Table 8.3   Property value within one block of coast of Hawaii in 2001 (billion US$)

	Oahu	Maui [a]	Big Island	Kauai [a]
Condo	0.85	0.70	0.39	0.30
Residential	11.29	1.18	0.65	0.73
Hotels	2.72	1.24	1.09	0.54
Total	14.86	1.56	2.12	0.96

[a]   Value transfer from the Oahu and Big Island property values on the basis of resident numbers in 2001 for residential properties and on the basis of visitor numbers in 2001 for hotel and condo property values.

On the basis of the expert judgment of real estate agents we assume that 1.5% of the sale price of the properties is attributable to the marine ecosystem. In addition, we only value this component at the actual selling of the property. The frequency of which condo's, residential houses and hotels change owner is assumed to be every 5, 10 and 6.5 years. The second column of Table 8.4 shows the annual reef-related property value of the main four Hawaiian islands.

Table 8.4   Annual reef-related property value in Hawaii in 2001

	Total value Hawaii *(in million US$)*	Reef-related value *(in million US$)*	Share of total value *%*
Condo	2,237	7	0.30
Residential	13,846	21	0.15
Hotels	5,587	13	0.23
Total	19,498	40	

8.3 Fishery value

Munro (1984) presents estimates of a sustainable harvest of edible finfish and invertebrates of 15 mt/km2/yr. Yields for each of these vary significantly. Russ (1991) summarizes 11 studies on yields of small coral reefs with estimates ranging from 0.42 to 36.9 metric tons of reef-fish per km2 per year. According to Russ (1991), these differences may be due to the size of the reefs, the level of effort and the definition of

reef fish. In addition, it can be due to the definition of the total reef area. This depends on the assumption of the maximum depth reef fishing; Russ (1991) quotes an example of a yield estimate of 24.9 metric ton/km2/year when the area estimate is based on a maximum depth of 60 meters; with a 20 meter maximum, the yield would have been 48.79 mt/km2/year; a depth of 40 meter is often taken as a standard.

On the basis of the above considerations, Russ (1991) suggests that sustainable yields in the order of 10-20 metric ton/km2/year are feasible for small areas of actively growing coral reef. This is in line with McAllister (1988) who assumes sustainable yields of 18 mt/km2/year for reefs in excellent condition, 13 mt/km2/year for reefs in good condition and 8 mt/km2/year for reefs in fair condition. It also corresponds to a summary by Alcala (1988) on three Philippine islands with yields ranging from 10.94 to 24 mt/km2/year.

Table 8.5 shows for Hawaii 12,273 mT of commercial marine landings of which 2.7% in value terms is reef-associated. With an area of 2536 km2 of reefs (*i.e.* potential coral reef area in both State and Federal waters of Main Hawaiian Islands; Gulko et al. 2002), this gives an average yield of 0.1 mT per km2 per year. This is very low. There are three explanations: (i) overfishing is severe; (ii) coral reef areas in Hawaii are less productive than corresponding reef areas in Southeast Asia as they are quite far from the epicenter of marine biodiversity (Indonesia/Philippines/PNG) where the estimates presented in Russ (1991) came from; and/or (iii) the definition of coral reef area in the official statistics of Hawaii is of reefs up to 100 meter depth, implying that this potential reef area may be considerably larger than the actual reef area. It is likely that all three factors are quite important.

If we assume that the 1660 km2 of reef is much too large, and with lack of other comparable data, we put fisheries on Hawaii at a yield of 5 mT per km2 per yr. Furthermore, we assume average fish prices of US$ 5 per kg and a value added percentage of 60%, in line with those reported in Kona (see Chapter 6). Finally, we take a multiplier of 40% for fisheries. This gives a total reef-associated fishery benefit of $1.3 million per year.

Table 8.5   Annual reef-related fishery value in Hawaii in 2001

Species group	Quantity	Total value	Reef dependency	Reef-associated fishery revenue	Reef-associated fishery benefit
	(MT)	*(million $)*	*(%)*	*(million $)*	*(million $)*
Tuna	6393.8	31.0	0	0	0
Billfish	2882.8	12.5	0	0	0
Misc. pelagic	1540.8	5.8	0	0	0
Deep bottomfish	329.9	2.4	0	0	0
Akule/Opelu	627.2	2.0	0	0	0
Inshore fish	140.1	0.6	100	0.6	0.5
Other (lobster, etc.)	259.0	1.8	50	0.9	0.8
Total	12273.6	55.9	2.7	1.5	1.3

Source: DAR (2000) website and our own calculations.

8.4 Biodiversity value

We distinguish two components of the biodiversity value that are relevant for the Hawaiian reefs. These include the research value and the non-use value. The research value is determined in a rather straightforward manner. All research budgets that are assigned to coral reef ecosystems in Hawaii is included in this value category. To determine this value a brief survey was held. All potential research candidates were asked to provide us with their annual budget for 2001. Table 8.6 shows the list of research organizations that are one way or another involved in reef related research. The sum of these activities amounts to US$ 10.5 million in 2001. One amount of $3 million of the National Marine Fisheries service has been excluded because it involves the removal of debris from the reef and is therefore not considered as a scientific value of the coral reef but rather as a cost of management.

Table 8.6   Hawaiian coral reef-related research funds allocated in 2001 (in US$)

Research source	Amount
1. Calibration Support for Hawaiian Reef Mapping	73,809
2. Assessment of Invasive Introduced Micro algae in Hawaii	60,077
3. Research and outreach to Prevent /control Aquatic Nuisance Invasions	34,231
4. Linkage between a Tropical Watershed and a tropical reef	195,306
5. Pacific Island Coral reef research, Management and Monitoring	356,000
6. USGS Reef Structure and Environmental History	60,000
7. USGS Reef Structure and Environmental History	98,000
8. USGS Continuation of Reef Stratigraphy and Evolution	34,040
9. USGS South Molokai Marine Investigations coral reef Biologic Component	76,367
10. Hanauma Bay Carrying Capacity	100,000
11. Hawaii Marine Protected Areas	45,000
12. Aquaculture of Marine Ornamentals	37,800
13. Hawaiian Marine Algae	397,700
14. Impact of Coral Bleaching on Coral Reef Fish Communities	22,485
15. Effects of Marine Protected areas on Reef Communities	72,000
16. GIS Data base Historical Layer development for Pacific Corals	10,000
17.Nature Conservancy	377,000
18.National Marine Fisheries Service (excl. debris)	3,300,000
19.Western Pacific Fisheries Management Council	n.a.
20. Dept of Aquatic Resources	400,000
21. Aquarium	2,300,000
22. Coastal Zone	170,000
23. Soest	1,325,950
24. SSRI	900,000
Total value	10,445,765

As described in Chapter 2, non-use values are based on the fact that people are willing to pay some money amount for a good or service they currently do not use or consume directly. In the case of the Hawaiian coral reefs they are not current visitors but derive some benefit from the knowledge that the reef exists in a certain state and are willing to pay some money amount to ensure that actions are taken to keep the reef in that state.

Sprugeon (1992) indicates two factors, representing the supply side and the demand side, which have a significant impact on the magnitude of the non-use values of coral reefs:

1. Values are positively related to the quality and uniqueness of the coral reef on both national and global scales. This supply side factor implies that the existence of many other similar sites would reduce the value. For the Hawaiian reefs it can be claimed that on the one hand the reef is unique because of the presence of a large number of endemic species, but on the other hand is not special because of the relatively limited number of species.
2. The size of the population, and their level of environmental awareness, will be positively related to non-use values. This demand side factor implies that the Hawaiian reefs are in relatively great non-use demand. Most reefs in the world are located in developing countries and therefore have a rather poor and uneducated audience.

To determine the non-use value for the Hawaiian reefs we adopt the approach used by Leeworthy and Wiley (2000). In their study for the Tortugas Ecological Reserve they calculate a non-use value assuming that 1% of the US population would have a willingness to pay for the reserve. They apply three values, $3, $5 and $10 per household per year. From our own survey we found that the involvement of Hawaiian residents with coral reefs is very high. Therefore we assume that for this group, all households have a willingness to pay of $10 per year. For the remaining group, the mainlanders, only 1% have a non-use value of the lower bound, $3 per household per year. This results in a total non-use value of $7.4 million per year.

Table 8.7   Calculation of non-use value for Hawaiian reefs in 2001 (in US$)

Region	Total number of households in region	Share of households with non-use value	Number of households with non-use value	WTP	Total non-use value
Hawaiian residents	400,000	100%	400,000	$10	$4,000,000
Main residents	113,000,000	1%	1,130,000	$3	$3,390,000
Total value					$7,390,000

Source: WTP estimates from Leeworthey and Wiley (2001), p.59.

8.5 Total economic value

The final step in valuing the coral reefs of Hawaii is to sum up the individual benefits into a total economic value. This requires assumptions about how the benefits change over time, the time period considered and the discount rate at which the annual benefits are aggregated. The most obvious approach would be to design a "with" and "without" scenario for the coral reefs in Hawaii. However, because the reef types vary greatly and the types of threats are so diverse, no Hawaiian wide intervention in coral reef management can be defined. Therefore, we assume that the benefits remain constant over time, with taking into account a management regime. The time period considered is similar to the 50 years considered in the case studies. The results will be presented at a discount rate of 3%, however, to demonstrate the impact of this selection a sensitivity analysis for a range of discount rates will be performed.

The last column of Table 8.8 shows the composition of the main economic benefits of the coral reefs in Hawaii. The average annual value of the coral reef ecosystem amounts to $364 million. This leads to a net present value at a discount rate of 3% of nearly $10 billion. Without discounting this value would be nearly $19 billion, while at a discount rate of 15% the net present value amounts to $2.8 billion. These high numbers certainly indicate that it is worthwhile, both from an ecological and an economic perspective, to take care of this valuable resource.

With an average annual benefit of $304 million, the recreational value dominates the overall value. This implies that almost 85% of the value of the Hawaiian reefs is dependent on tourism, and visa versa, that tourism is very dependent on the state of the coral reef of Hawaii. Second is the amenity value with a value of $40 million per annum. Although the impact on the property value is minimal, the magnitude of the overall value of properties in Hawaii is substantial, thereby still generating a high coral reef related value. The third most important benefit is the biodiversity value. The scientific value is a rather solid estimate and therefore does not require more effort. The non-use value of the Hawaiian reefs, on the other hand, are estimated on the basis of a rather simple approach and are therefore candidate for improvements. New results in the field of the non-use values are expected from a study by Leeworthy and Wiley within the near future. Typically, the fishery value is the least important reef related benefit.

Table 8.8 also provides a comparison between the different case studies. This comparison confirms the danger of generalizing economic benefits estimates for Hawaiian reefs in general. The value estimates vary widely in terms of both the overall level and the configuration of the benefits. For example, were recreational benefits are the most important value at Hanauma Bay, it is the amenity benefits that dominates the overall value at the Kihei coast.

Table 8.8   Annual benefits and the net present value of the Hawaiian coral reefs and the different study sites

		Hanauma Bay, Oahu	Kihei Coast, Maui	Kona Coast, Hawaii	Hawaii - overall
Recreational value	*Million$/year*	36.23	8.02	8.06	304.16
Amenity value	*Million$/year*	0.00	18.26	4.47	40.05
Biodiversity value	*Million$/year*	1.11	1.71	4.35	17.00
Fishery value	*Million$/year*	0.01	0.10	0.70	2.50
Education spill-over value	*Million$/year*	0.22	-	-	-
Total annual benefits	*Million$/year*	37.57	28.09	17.68	363.71
Net Present Value @ 3%	*Million$*	1,053	522	389	9,722

By reporting the total values on a per area basis, Table 8.9 enables the comparison of the three case studies in absolute levels. Not surprisingly, Hanauma Bay is the most valuable site of coral reefs in Hawaii, and perhaps even in the world. This is all due to the high recreational use of the Bay. In fact, the reefs at Hanauma Bay that can be categorized as ecologically average coral reefs for Hawaiian standards are more than 125 times more valuable than the reefs at the Kona Coast that are often considered to more ecologically diverse. This demonstrates that economic values and economic values do not always go hand in hand.

Table 8.9   *Annual benefits and net present values of the different case study sites per area of coral reef*

		Hanauma Bay, Oahu	Kihei Coast, Maui	Kona Coast, Hawaii
Total annual benefits	$/m^2$	91.63	3.51	0.73
Net Present Value	$/m^2$	2,568	65	19
Total annual benefits	$/acre	370,819	14,210	2,944
Net Present Value	$/acre	10,393,033	264,231	78,698

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Appendix I. Nutrients and eutrophication

The waters surrounding coral reefs are typically oligotrophic or low in concentrations of inorganic nutrients (nitrogen and phosphorous). Under these circumstances, reef building corals usually dominate and fleshy algae are kept in low abundance because of a combination of both low nutrients and high grazing activity from fish and invertebrate species. It has been suggested that by altering either of these factors (nutrient levels or herbivory) that the competitive interaction between corals and algae will shift. Increasing nutrient levels may accelerate algal growth rates to a point where they may overgrow corals and/or by reducing herbivore pressure algae will be able to grow "unchecked". While there is some evidence that phosphorous may decrease rates of calcification in corals most of the literature suggests that the largest effect of increased nutrients on coral reefs is by the response of the algal community. In some cases herbivores be abundant enough to make up for any differences in algal growth caused by enhanced nutrient supply. Phase shifts from coral to algal dominance are typically believed to be the result of both increased nutrients and reduced grazing pressure as a result of overfishing or disease.

Coral reefs are particularly susceptible to sewage pollution because of the delicate ecological balance maintained among a large number of species. The natural low levels of nutrients in tropical seawater are partly responsible for maintaining that balance. Sewage pollution disturbs that balance by nutrient enrichment, which will favour certain species, usually at the expense of reef corals, and will lead to alteration of community structure (e.g. Marszalek, 1987; Grigg and Dollar, 1990; Maragos et al., 1985). Other effects of sewage pollution include toxicity (from toxic materials or toxic by-products from pesticides, herbicides or heavy metals contained in sewage), sedimentation (suspended solids), high biochemical oxygen demand, and hydrogen sulphide generation (Grigg and Dollar, 1990; Pastorok and Bilyard, 1985). However, most of the impacts from sewage pollution on coral reefs reported in the literature relate to the nutrient enrichment rather than to toxic effects. The literature suggests threshold levels for dissolved inorganic nitrogen (DIN) of 1.0 mM and for soluble reactive phosphorus (SRP) of 0.1 mM (see for example Lapointe et al., 1997).

Other impacts of sewage pollution include a decline in growth rate of corals (Tomascik and Sander 1985), reduced calcification (Kinsey and Davies 1979), reduced planulae production (Tomascik and Sander 1987), reduced fertilization success of gametes (Harrison and Ward 2001) and reduced settlement of coral larvae (Tomascik 1991, Ward and Harrison 1996).

In her survey of coral reef degradation in the Caribbean, Rogers (1985) identified sewage as one of the human-related stresses in 9 of the 25 islands or areas for which information was available.

Bell (1991) describes the impact of wastewater discharges from tourist resorts in the Great Barrier Reef, Australia. Two of the most visited islands, Hamilton and Green Island, have discharged virtually untreated sewage in the sea for quite some time. The

coral communities at Green Island have been largely replaced by algae and seagrasses. He also recognizes the impact of discharges of secondary treated sewage and sludge from Townsville on the coral reefs of Magnetic Island, just off Townsville. He expects seepage from sewage on Magnetic Island to be disastrous for the already stressed corals. He concludes that tertiary treatment of sewage will be necessary to achieve acceptable levels of nutrients (after dilution) in the discharged effluent. In comparing these findings with the Caribbean, we must realize that mean background phosphate levels for the waters outside the Great Barrier Reef are higher than those reported for the Caribbean.

Van Woesik et al. (1991) examined the response of coral communities to effluent discharge on Hayman Island, Green Island and John Brewer Reef in the Great Barrier Reef Marine Park. Except in the immediate vicinity of the sewage discharge outfall, they found no impact from discharge of secondary treated sewage from the resort on Hayman Island. On Green Island sewage from septic systems is subject to primary treatment before discharge. They attribute the increase in seagrass beds to nutrient enrichment from sewage discharge. At John Brewer Reef Floating Hotel (removed in 1989) treated sewage was transported and discharged 5 km off the reef and the only effluent discharged was brine from the desalination plant. Overall, coral cover increased in the vicinity of the hotel and the authors conclude that there was no detrimental impact of its placement or operations. They suggest that the impact of sewage discharges on coral communities is mostly dependent on the level and quality of treatment.

There are some field studies in which nutrients were experimentally enhanced. In 72 ammonium and phosphate were added to a patch reef at One Tree Island (GBR). Nutrient addition increased primary production (photosynthesis) (Kinsey and Domm 1974) and reduction of calcification . The experiments were repeated in a broad scale set up with multiple patches with different nutrient additions and measurements of a wide range of variable in 1993-1996 in the ENCORE project. Hoegh-Guldberg et al. (1997) studied the impact of nutrient enrichment in the Great Barrier Reef as part of the ENCORE project (Enrichment of Nutrients on Coral Reefs Experiment). Nitrogen and phosphorus (10 mM NH_4 and 2 mM PO_4 were added to experimental corals on micro-atolls. Although the results of the experiment were not conclusive, it is suggested that increased levels of phosphorus have a negative effect on coral growth. Strong seasonal variation in calcification rates appears to have masked the impact in the experiment. The final conclusions of ENCORE sum up to: increased coral mortality, decreased coral growth, increased calcification but lower skeletal density (weak structure) and reduced settlement of larvae (Koop, et al. 2001).

Simmons and Associates (1994), in their study of the impact of tourism on the marine environment of the Caribbean, note that "….the impact of liquid waste from yachts has been poorly studied in the Caribbean region. While it is very likely to have an effect on water quality in lagoons and semi-enclosed bays, its impact is probably small or negligible in open bays with adequate flushing." Talge (1992) also touches on the issue of nutrient enrichment by diver activities and boat effluents. She raises the question: "…. But are the amounts significant and do they remain over and around the reef long enough to fertilize reef communities?" These questions have remained unanswered to date.

An interesting quote from the abstracts of the 10th International Coral Reef Symposium in Bali of which the proceedings will hopefully come out shortly: Bucher, D.J. "Ammonium reduced the ability of corals to repair lesions, a result which has implications for the recovery of polluted reefs following physical damage."

The hampering of natural restoration through reproduction is of utmost importance: "The point is, while levels of stress may be sub-lethal to adult coral colonies, they may be sufficient to cause reproductive and recruitment failure on nearby and distant reefs (Richmond 1993). Reefs may still hang in there, but where is a future without new generations?

Nutrients can either lead to reduced coral cover by direct harmful effects or by stimulating algae which then outgrow and out-compete corals. Well known cases of coral-algal phase shifts are Kaneohe Bay in Hawaii (Smith, et al. 1981) and Jamaica (Hughes 1994). For simplicities sake the mechanism of influence is by-passed and a direct relation between nutrients and coral cover is sought, because the problem with algal overgrowth is hugely complex, uncertain ("Competitive outcomes did not support the argument that algae are more successful competitors in more eutrophic conditions" (McCook 2001)) and difficult to quantify (McCook 1999, McCook 2001, McCook, et al. 2001). Field data have been chosen from Barbados (Tomascik and Sander 1985, Tomascik and Sander 1987, Wittenberg and Hunte 1992), Brazil (Costa, et al. 2000), Curaçao (Gast 1992, Gast 1998, Gast, et al. 1998, Gast, et al. 1999), Kaneohe Bay (Smith, et al. 1981, Hunter and Evans 1995) and Reunion (Naim 1993), which are used to distil relationships between nutrients and coral cover and the number of coral species. Figure I.1 includes the data of all these studies and shows that there is a general trend of higher concentrations causing lower cover. Extremely high concentrations are always accompanied by cover close to zero. A few corals always appear to be able to survive with high nutrient concentrations, but one can hardly call these a reef. Cut-off concentrations have therefore been chosen and higher values have been removed from the data set. The relationships of coral cover with phosphate is very week. Apparently, forms of nitrogen have a more linear effect on coral cover (Figure I.2). The final choice is for DIN rather than either nitrate or ammonium, because:

- Ammonium is rapidly converted via nitrite to nitrate by nitrifying bacteria in the reef water column and sediments.

- The conversion of urea to ammonium to nitrite to nitrate also takes place in the sewage system. As these processes are oxygen dependent, mainly ammonium enhanced with direct discharge of untreated sewage, but an unknown mixture of ammonium and nitrate is brought into the water column with the outflow of a sewage treatment plant.

- Groundwater seepage always and mainly leads to enhanced nitrate concentrations, because the long residence times give ample opportunity for the conversion.
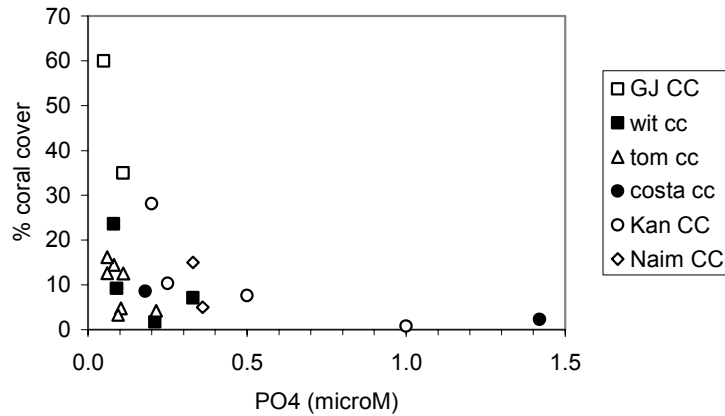
Figure I.1   Decreasing coral cover with increasing phosphate concentration. 'GJ' is data Curaçao, 'wit' and 'tom' are data Barbados, 'costa' is data Brazil, 'Kan' is Kaneohe Bay, 'Naim' is data Reunion. References of these studies are mentioned in the above text. Phosphate is an example; forms of nitrogen show the same pattern.
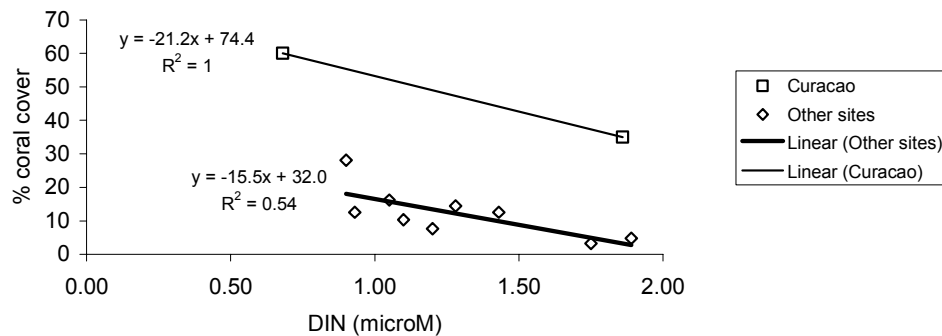

Figure I.2   Decreasing coral cover with increasing DIN values (NH4 + NO2 + NO3). Other sites is collection of refs in legend Fig 1, excluding values > 2. For coral cover the data from Curaçao have been separated from the rest of the data set, because the show a far higher coral cover with comparable nutrient concentrations (the cause could be different local circumstances or a difference in methods with which the data were obtained).

Hence the use of DIN includes bacterial conversion effects and covers both sewage discharge and groundwater seepage. As the slopes differ with a stronger effect of ammonium, one of the other figures could be applied accordingly in areas where the main eutrophication cause is known. The number of scleractinian corals also decreases with eutrophication. DIN is chosen again, because it shows the strongest relation (Fig 3) and to be consistent with the coral cover equation.

Equations:

- % coral cover = 32 – 15*DIN (mM)
- % coral cover = 31 – 30*NH4 (mM)
- % coral cover = 19 – 13*NO3 (mM)
- # coral species = 33 – 11*DIN (mM)
- # coral species = 31 – 22*NH4 (mM)
- # coral species = 33 – 22*NO3 (mM)

Remarks:

- Regressions of # coral species Barbados and Curaçao data

- For coral cover the data from Curaçao have been separated from the rest of the data set, because the show a far higher coral cover with comparable nutrient concentrations (the cause could be different local circumstances or a difference in methods with which the data were obtained).

- Although it is ridiculous to draw a line through two points, this has only been done to show that the slopes of the lines are comparable and that the patterns at Curaçao are comparable to those of all other sites combined regardless of the higher cover.

- Correlation coefficients are included in the excel sheet. However, as the measuring error of nutrients is negligible compared to the uncertainties in establishing coral cover and because there is an a priory accepted effect of the X variable on the Y variable, regression is assumed to be justified.

The final choice in for modelling nutrient pollution is to concentrate on DIN rather than either nitrate or ammonium, because: (1) Ammonium is rapidly converted via nitrite to nitrate by nitrifying bacteria in the reef water column and sediments; (2) The conversion of urea to ammonium to nitrite to nitrate also takes place in the sewage system. As these processes are oxygen dependent, mainly ammonium enhanced with direct discharge of untreated sewage, but an unknown mixture of ammonium and nitrate is brought into the water column with the outflow of a sewage treatment plant; and (3) Groundwater seepage always and mainly leads to enhanced nitrate concentrations, because the long residence times give ample opportunity for the conversion.

Hence the use of DIN includes bacterial conversion effects and covers both sewage discharge and groundwater seepage. As the slopes differ with a stronger effect of ammonium, one of the other figures could be applied accordingly in areas where the main eutrophication cause is known.

The number of scleractinian corals also decreases with eutrophication. DIN is chosen again, because it shows the strongest relation (Figure I.3) and to be consistent with the coral cover equation.
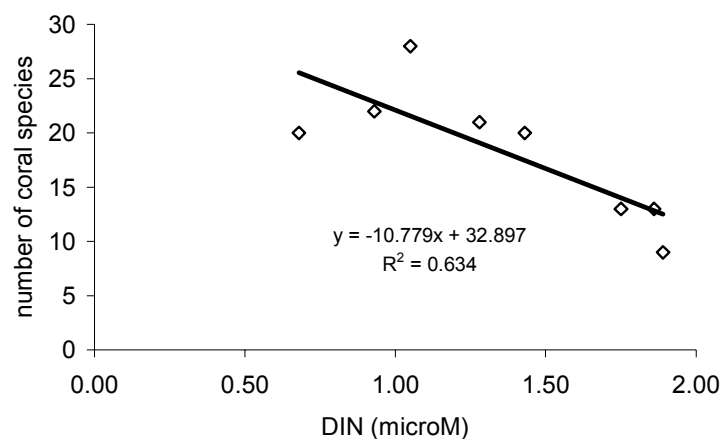

$$y = -10.779x + 32.897$$
$$R^2 = 0.634$$

Figure I.3   Decreasing number of stony coral species with increasing DIN concentration. Data from Curaçao and Barbados (see earlier references).

Appendix II. Sedimentation

Sedimentation resulting from anthropogenic influence occurs almost always concomitant with eutrophication. Major reviews of anthropogenic disturbances on reefs (Pastorok and Bilyard 1985, Grigg and Dollar 1990, Richmond 1993, Dubinsky and Stambler 1996) both address sedimentation and eutrophication. In practice, both are usually the result of urbanization, coastal development and changes in land use (e.g. deforestation), which increase run-off and/or sewage discharge. It is often difficult to seperate the individual effects of the 2 influences (Walker and Ormond 1982, Tomascik and Sander 1985, Tomascik and Sander 1987, Tomascik and Sander 1987, Tomascik 1991, Bak and Nieuwland 1995, Connel 1996). However, it is clear that sedimentation alone is an important threat to the health of coral reefs (see also quote RS Young below).

Grigg and Dollar (1990), in their review of natural and anthropogenic disturbances on coral reefs, state: "The impact of increased sedimentation is probably the most common and serious anthropogenic influence on coral reefs." Increased sedimentation results primarily from dredging and runoff. Dredging, runoff or siltation were mentioned as one of the human-related stresses on coral reefs in Barbados, Bermuda, Bonaire, Costa Rica, Curaçao, Dominican Republic, Florida Keys, Grenada, Guadeloupe, Jamaica, Panama, St. Lucia, British Virgin Islands and US Virgin Islands (Rogers, 1985). Rogers (1990) associates dredging in the Caribbean with construction of hotels, condominiums, runways, roads, harbors, navigation channels, military installations, and beach replenishment. She states: "Unprecedented development along tropical shorelines is causing severe degradation of coral reefs primarily from increases in sedimentation."

Background levels of sedimentation on reefs that are not influenced by human activities are between 1 and 10 mg per cm2 per day (Rogers, 1990). She suggests that chronic sedimentation rates above 10 mg per cm2 per day are "high". The relevance of this threshold is shown in Kenya, where sedimentation values of 1.35 and 4.25 mg/cm2/d did not lead to differences in coral cover (McClanahan and Obura 1997). Sudden exposure to heavy sedimentation may result in burying of corals, expulsion of the symbiotic algae from the coral polyps ("bleaching"), and subsequent death. Other effects of increased sedimentation (varying from 200 to 800 mg per cm2) include: no effect, reduced growth, reduced calcification (33%), decrease in net production, and increase in respiration. Coral species respond differently to heavy sedimentation and some are more efficient in rejecting sediment than others. Bak and Elgershuizen (1976) found that *Acropora palmata*, *A. cervicornis*, *Porites astreoides* and *Agaricia agaricites* were the least efficient and *Colpophyllia natans, Diploria strigosa* and *Madracis mirabilis* were among the most efficient. Rogers (1990) summarizes the results of field and laboratory studies as follows:

1. Different species have different capabilities of removing sediment or surviving at lower light levels.
2. The coral's ability to remove sediment depends on the amount and type of sediment, which covers the coral colony.
3. Sediment rejection is a function of morphology, orientation and behavior of a coral colony.

4. Experimental corals may not behave normally in the laboratory.

Chronic exposure to higher concentrations of sediment can have a variety of negative impacts on corals, many of which can be attributed to reduced light levels. These include (Rogers, 1990):

1. Lower species diversity and absence of certain species.
2. Less cover by live coral.
3. Lower coral growth rates.
4. Greater abundance of branching forms.
5. Reduced coral recruitment.
6. Decreased calcification.
7. Decreased net productivity of corals.
8. Slower rates of reef accretion.

Marszalek (1981) monitored the impact of a large-scale dredging operation for beach replenishment in Miami, Florida. He distinguished three types of impact: mechanical damage, sediment loading and increased turbidity. A substantial percentage of coral colonies showed signs of stress such as partial bleaching, polyp swelling and excessive mucus secretion. He suggests that sustained increased turbidity was more detrimental than short-term sediment loading.

During a 9 months dredging operation in 1987 in Thailand reefs subject to the resulting sedimentation showed significant decreases of coral cover and coral diversity (Brown 1990). However, these reefs were recovered in 1988 to pre-dredging levels.

Work by Hubbard et al. (1987) in St. John, US Virgin Islands, demonstrates a gradual decrease in growth by 10-20% over the past 100 to 200 years. Their data suggest that this decline may be due to increased sedimentation following the cultivation period of the island.

Van't Hof (1983) describes the effects of dredging and excavation (to construct a canal system and waterfront home sites in a limestone cliff) on the fringing reef in Bonaire. Dredging resulted in sediment loading of almost 100 times the background level and a decrease in percent live coral cover adjacent to the dredge site. The largest change in percent live coral cover was observed on the lower reef slope (35m depth, dominated by Agaricia lamarcki) from 73% cover pre-dredging to 32% post-dredging.

Hodgson (1990) determined that sedimentation inhibited settlement of coral larvae on artificial substrate in a common Indo-Pacific coral species, thus potentially affecting coral recruitment under natural circumstances.

Extensive studies on effects of sedimentation in combination with eutrophication are those done at Barbados by Tomascik & Sander. They measured both suspended particulate matter (SPM), which is an indication of particles in the water column, and total downward flux of SPM (DF-SPM), which shows how many of those particles sink down on corals on the bottom. Comparisons of the sampling stations show that these two variables do not always follow the same trend: a large amount of particles in the water column does not necessarily lead to high downward sedimentation. The significance of difference between the 2 variables lies in the mechanism of damage: the former reduces light available to corals and thus photosynthesis, while the latter leads to smothering, which corals have to remove. The end result is in so far the same that the coral has less

energy available and is weakened. Rather surprisingly, there was a significant negative relation between SPM and coral cover, but not between DF-SPM and coral cover. However, this last correlation did become significant when only the summer data were used. Apparently, the physical circumstances (current, waves) determine whether sediment rains down or stays suspended in the water column. The studies mentioned above show reductions of coral growth rates, cover, coral species, diversity, numbers of larvae, settlement, and changes in coral community composition.

Another Caribbean island where extensive studies have been done on anthropogenic effects is Curaçao. Aspects of corals and coral reef ecology have been compared between influenced sites directly in front of Willemstad and non-affected sites upcurrent. Increased sedimentation has been measured by Meesters (Meesters, et al. 1992). This sedimentation caused a reduced capacity to heal artificial lesions (Gast 1992, Meesters, et al. 1992). Comparison of the coral reef community (chain line transect method, the coral species or substrate type under each chain was scored) at the impacted and control sites showed a reduction of coral cover from circa 60% to 35%, a reduction of the number of coral species from 20 to 13 (9 m depth) and reduction of the coral diversity index (Shannon-Weaver) from 2.33 to 1.65 (Gast 1992). The whole coral community had been changed quite drastically. The control reefs showed a high variety in species and growth forms of virtually only stony corals. But reefs in front of Willemstad are dominated by head corals (Siderastrea siderea, Diploria strigosa, Colpophylia natans, Montastreae annularis, Montastreae faveolata, Montastreae cavernose, Dichocoenia stokesii). Soft corals and sponges were rare at the control site, but far more abundant at the impacted site. Branching and leaf-shaped corals (Acropora palmata, Agaricia agaricites, Porites porites, Millepora complanata, Eusmilia fastigiata) were absent or strongly reduced (Gast 1992).

Some interesting quotes from the abstracts of the 10th International Coral Reef Symposium in Bali of which the proceedings will hopefully come out shortly:

Schelten, C.K. "The number of juveniles was significantly lover on the sediment gradients compared to the control. This was linked to an altered juvenile coral composition, probably towards more sediment tolerant species…. the percentage of damaged juvenile increased while the average size decreased with sedimentation".

Ortiz, J.C. Studied coral reef in Venezuela before and after landslides resulting from intense rain. "Coral cover decreased 42% and the number of species from 22 to 17".

Young, R.S. Monitoring of reefs in Honduras (Roatan) in the vicinity of broadscale tourism industry development. "Initial results suggest that reef mortality is more closely tied to increases in sedimentation rather than degradation of water quality."

Dose response relations of the effects of sedimentation are scarce to absent in the literature. A mathematical relationship is presented in Fig. 4 of the review by Pastorok and Biljard (Pastorok and Bilyard 1985). These response curves were calculated with the original data collected at Guam (Randall and Birkeland 1978). Data were collected from upper slope communities and the lines were fitted using least-squares linear regression. The resulting equations are

- $\ln Y = 4.97 - 0.018X$ for the effect of sedimentation on the number of coral species
- $\ln Y = 3.17 - 0.013X$ for the effect of sedimentation on percent coral cover

X in sedimentation rate (mg.cm-2.day-1). Y is coral species (number) or coral cover (%), respectively. A problem arises with the maximum number applying this equation to other regions. The value of e4.97 is 144 species of corals, which is not realistic for Hawaii or the Caribbean. The number of stony coral species is 55 in the Hawaiian Archipelago (Wilkinson 2000) and in the Caribbean there are roughly 70 species. Hence values of 4.01 and 4.25 should be used when the model is applied to Hawaii and the Caribbean, respectively.

Finally, reef degradation is also partly responsible for a decline of reef fisheries. Sedimentation can kill major reef-building corals, leading to the eventual collapse of the reef framework. The reduction in the percentage of living coral as well as the decrease in the amount of shelter that the reef provides leads to a decline in the number of reef fish and the number of species (Rogers, 1990).

Appendix III. Physical anthropogenic damage

Several authors have researched and documented snorkeler and diver damage. It is often difficult to distinguish such damage from natural damage or other forms of human-induced damage (for example, see Rogers et al., 1988). This points to the need to design research methods that will target a specific issue and eliminate compounding factors. Hawkins and Roberts (1993b) and Scura and Van't Hof (1993) have applied such methods by comparing heavily dived and little dived areas and by looking at gradients of impact along a line of decreasing recreational activity.

Rogers et al. (1988a, 1988b) monitored coral breakage at two reefs in the Virgin Islands National Park and Biosphere Reserve (VINP), as well as individual Elkhorn coral colonies (*Acropora palmata*). They attributed broken coral branches to careless snorkelers, boat strikes and swells. They noticed divers and snorkelers bumping into corals or standing on them, and overturning corals to reach lobster. Even in the absence of major storms or other stresses, only 10 of 50 tagged Elkhorn coral colonies remained undisturbed over a 7-month period of observation. Rogers et al. (1988a) report that at Trunk Bay in VINP, where a snorkeling trail was established in the early sixties – receiving 170,000 visitors annually by 1986- ".... the trail has deteriorated substantially as a result of people standing on corals, breaking coral branches while snorkeling, and removing organisms as souvenirs."

Tilmant (1987) and Tilmant and Schmahl (1981) studied the impact of recreational activities on buoyed reefs in Biscayne National Park, Florida. Each buoyed reef received three or more times as much use as its control. The most frequent recreational activities were snorkeling and spear fishing. The mean frequency of damaged coral encounters ranged from 35 to 140 per 30-minute count. Although significant differences in damage between buoyed reefs and controls did occur at some sample points, such differences did not follow a consistent pattern that could be readily attributed to human use. Incidence of damage to soft corals was much higher than that to hard corals. They recognized that, since the level of recreational use on the reefs studied was relatively low (no more than 1,500 people per reef per year), the impacts may be more severe at higher levels of use.

Talge (1991) studied the behavior of snorkelers and SCUBA divers in the Looe Key National Marine Sanctuary, Florida, in terms of the number of interactions between divers and coral. The interactions she observed were:
- Hand on the coral to steady or help gain control
- Kicking or brushing with the fins
- Standing on corals
- Grabbing corals (especially soft corals) to pull themselves through the water
- Rubbing against coral with any part of the body
- Sitting coral with the SCUBA tank or other pieces of equipment
- Creating sediment clouds

The most frequent interactions were "finning" and "push-off". The average number of interactions per diver is ten per dive. Snorkelers had significantly less interactions than SCUBA divers, divers without gloves had fewer interactions than divers with gloves, and females had fewer interactions than males. Over two-thirds of the interactions were

with hard corals. This contrasts with the findings of Tilmant and Schmahl (1981) and may well be due to the selection of the study sites, one being comparatively richer in soft corals than the other. Coral breakage included only 0.6% of all incidents. This author also expressed concern with increase in nitrogen concentration of the water by divers urinating over the reef. This concern has not been substantiated by further research.

An experimental study by Talge (1992) in the Looe Key National Marine Sanctuary, Florida, consisted of weekly "touching" and "finning" selected corals at two intensities. Weekly touching had no detectable lasting influence on the health of 11 species of corals, either visibly or histologically. Based on an average of 10 interactions per diver, she calculated that 4-6% of the live coral area is touched weekly. However, as a small percentage of divers have much more frequent interactions, she recommended that the touching ban in the Sanctuary be maintained.

Scura and Van't Hof (1993) and Dixon et al. (1993) describe diver impact in Bonaire, Netherlands Antilles. A comparison of sites receiving high levels of use, intermediate levels of use and controls (reserve sites closed to diving) indicated that percent hard coral cover is significantly lower at high-use sites than at control sites, while species diversity is higher at high-use sites than at controls. At intermediate-use sites no such differences were found. The study also suggests that impact is decreasing with linear distance from the center of activity (in the case of Bonaire the dive boat moorings). Percent coral cover and species diversity increase with distance from the mooring. The findings led to the postulation of a "threshold" hypothesis that diver impact becomes quickly apparent when use exceeds a level of 4,000-6,000 divers on a dive site per year.

Hawkins et al. (1999) repeated the study of Scura and Van't Hof (1993) three years later. They found a decrease in coral cover at both control and dived sites, except at one of the sites labeled as high-use in the 1993 study. Their study showed that dive sites suffered no greater loss of coral cover than control sites in the three-year period. However they found a distinct difference in community structure between high-use and control sites. The proportion of massive corals that make up total coral cover decreased at both high-use and control sites, but the decrease was much greater at high-use sites (19.2% vs. 6.7% decrease). The proportion of branching coral increased 8.2% in high-use sites compared to 2.2% in control sites, with coral diversity and species richness showing a similar pattern. They conclude that there has been an increased disturbance of Bonaire's reefs over the three-year period between the studies, with greater disturbance in high-use areas than at control sites. A reduction in cover by massive species is also reported in Connell (1997) for Buck Island, St. Croix, US Virgin Islands. Although no explanation is offered for the decline, it is noteworthy that Buck Island is a location, which is subjected to heavy recreational use.

Tratalos and Austin (2001) conducted a study, similar to that of Scura and Van't Hof (1993) and Hawkins et al. (1999) in Bonaire, in Grand Cayman. They found significantly lower overall hard coral cover and massive hard coral cover at high intensity sites compared with low intensity sites and undived sites. There was also more dead coral and coral rubble at high intensity sites. A "distance effect" was also present, meaning that hard coral cover increased with distance away from the mooring buoy. Most of their results are similar to the findings of the Bonaire studies.

Several studies on diver and snorkeler damage have been conducted in other parts of the world. Although Indo-Pacific reef structure and species composition are different from that of most Caribbean islands (the former possessing extensive reef flats and more branching and foliaceous species), the results of these studies are nevertheless of value.

Allison (1996) researched snorkeler damage to reefs in the Maldive Islands. The study showed a positive correlation between the distribution of broken corals and snorkeling activity on the reef at Vihamanaafushi. The study concludes that: "....the observed breakage is important because of potential reduction of the aesthetic appeal of the reefs to tourists, and degradation of the reefs' ability to sustain the islands they protect and nourish." The author advocates, amongst others, programs to educate and train users to reduce damage, and to develop information packages and simple effective data collection methods suitable for amateurs. Networks of dive and tour operators could be used as the implementation vehicle for such programs.

Hawkins and Roberts (1993b) studied the effect of trampling by SCUBA divers and snorkelers on reefs flats of coral reefs in Egypt. They found significantly more damaged corals and loose fragments of live coral in heavily trampled areas than in little-trampled areas. Percentage of bare rock and rubble was significantly higher, while percentage of live coral cover and number of hard coral colonies were lower. Coral colonies were also smaller in trampled areas compared with control areas. In summary, heavy trampling by divers appears to alter the coral population structure of the reef flat. Although the Western Atlantic reefs do not have extensive reef flats as occur in Indo-Pacific reefs, some Caribbean islands have experienced or continue to experience the effect of divers and snorkelers treading on coral. Buccoo Reef in Tobago is probably the most infamous example of the destruction caused by reef walking (see Rogers et al., 1988b). Where shore diving is practiced, divers and snorkelers will also have some impact on shallow reef areas by trampling.

Hawkins and Roberts (1992a, 1992b, 1993a, 1993b, 1994) compared heavily dived and un-dived areas in Egypt and found significant differences in levels of damage. Numbers of broken hard coral colonies, live loose coral fragments, reattached fragments, abraded colonies, and part-dead colonies were higher in dived areas. They concluded that divers cause significant damage to benthic communities on the fore-reef slope. Their findings suggest that damage accumulates rapidly when a new site is opened up for diving, with impact stabilizing after a certain level of use had been reached. The three study sites received between 5,000 and 13,000 dives per year. Hawkins and Roberts (1994) suggest that dive sites at Sharm-el-Sheik in Egypt can accommodate 10,000 to 15,000 dives per year without serious degradation.

Epstein et al. (1999) compared populations of the hard coral Stylophora pistillata at a site that had been closed to the public for six years with two nearby sites, open to the public, in Eilat, Northern Red Sea. The main results of the study indicate that: (1) live coral cover was three times lower at the open sites than at the closed site; (2) there were significantly more small colonies (recruits) at the open sites and significantly less large-size colonies; (3) the average number of broken colonies was three times higher at the open sites. They interpret the lower breakage level in the closed site as a sign of the effectiveness of the closure, but they also conclude that a no-use policy is not sufficient for protecting small reef areas.

Jameson et al. (1999) developed a Coral Damage Index (CDI) to assess the extent and severity of physical damage to coral. Sites are characterized as "hot spots" if in any transect the percent of broken coral colonies is 4% or more, or if the percent cover by coral rubble is 3% or more. In a study of four diving sites off Hurghada and Safaga, Egypt, in the Red Sea, 40% of the transects surveyed qualified as "hot spots". The relatively large number of hot spots in shallow water suggests that most of the damage was caused by anchors dragging across the reef. They conclude that the diving carrying capacity of the sites is being exceeded by large amounts.

Muthiga and McClanahan (1997) compared the impact of visitor use (diving and snorkeling) in heavily used sites and less frequented sites. They found no significant differences in coral cover or bare rock and rubble between sites, nor differences in coral species composition and diversity. However, there was significantly more damage to coral in the high-use sites, as evidenced by the number of broken, abraded, and broken and reattached coral colonies. Greater damage as observed in shallow than deep areas, which may indicate that snorkelers have more impact than SCUBA divers. Differences between the results of this study and those in the Red Sea may be explained to a large extent by the much higher visitation levels in the Red Sea.

Davis at al. (1995) observed diver interactions in the Julian Rocks Aquatic Reserve in Eastern Australia. Thirty divers were observed for about 30 minutes each. The number of diver contacts ranged from 2 to 121 (average 35 contacts per dive). More than 50% were contacts made with fins. Only 7.2% of contacts resulted in noticeable level of damage. The majority of damaging contacts were with hard corals, with lesser damage inflicted on sponges and turf algae. More experienced divers (those with more than 100 logged dives) made significantly less uncontrolled contacts than less experienced divers.

Harriott et al. (1997) conducted a similar study of diver contacts at four other locations in Eastern Australia (Heron Island and Lady Elliott Island in the Southern Great Barrier Reef, and Gneering Shoals and Solitary Islands in sub-tropical Eastern Australia). There was a large range in the total number of contacts per diver per site, with a few divers having a disproportionate impact. This coincides with the findings of Rouphael (1995). The maximum number of contacts ranged from 192 at Gneering Shoals to 304 at Solitary Islands. There was a significant difference between the mean numbers of contacts between sites, ranging from 31.3 at Heron Island to 121.2 at Solitary Islands. The mean number of coral contacts follows more or less the same pattern, but there is no significant difference between sites in coral breakage. The mean number of corals broken per dive ranged from 0.6 at Heron Island to 1.9 at Solitary Islands. Most contacts were made by fins and 78% of coral breakage was caused by fins. Differences between the number of contacts and coral breakage per site were attributed to:

1. Greater awareness among divers at Heron Island and Lady Elliott Island (located within the Great Barrier Reef Marine Park), because of the awareness campaigns by the Great Barrier Reef Marine Park Authority and pre-dive briefings at these sites.
2. At Solitary Islands and Gneering Shoals, divers actively explored the small invertebrate fauna and thereby spent more time close to the bottom where they were more likely to make contact with corals.

Apart from the direct physical impact from diver and snorkeler contacts, such as breakage of coral and inflicting lesions, there is also some evidence that damaged corals show reduced growth rates (e.g. Liddle and Kay, 1987, and Meesters et al., 1994).

Table III.10 Mean values of coral cover, at near mid and far distances from the mooring buoys, at sites with high and low diver numbers

	Near	Mid	Far
		High diver numbers	
% hard coral	18.04	19.48	24.69
% massive coral	11.42	11.69	14.07
% dead coral	3.48	3.35	4.12
% coral rubble	1.39	3.15	0.85
		Low diver numbers	
% hard coral	28.9	33.93	30.97
% massive coral	19.44	24.71	23.88
% dead coral	1.64	2.07	1.67
% coral rubble	1.14	0.21	0.76
		Impact of less pressure	
Gain hard coral	60%	74%	25%
Gain massive coral	70%	111%	70%
Less dead coral	-53%	-38%	-59%
Less coral rubble	-18%	-93%	-11%

Source: Tralalos and Austin, 2001, p.72.

Appendix IV. Overfishing

This Appendix describes the economic and ecological consequences of overfishing and looks briefly at marine reserves as a way of coping with fishing pressure. Overfishing is different from the other threats described here, in that it does not have the same type of direct destructive impacts. Modest forms of non-destructive overfishing will, in fact, have very little impact on corals. Extreme forms of non-destructive overfishing could, on the other hand, alter the ecosystem balance, ultimately leading to a reef dominance by sea urchins or macro-algae and resulting in a dramatic drop in fishery yields and reduced coral biomass and productivity (McClanahan, 1995).

An interesting example of overfishing of invertebrates is given by a case of mother-of-pearls (Trochus spp.) in a village in Central Maluku (Indonesia) (Figure IV.4). A traditional management scheme, referred to as *sasi*, was in place with three year harvesting cycles. At some stage, annual harvesting was allowed, leading to severe overfishing of the resource. In the time of the 3-year closed season, the average yield was around 3400 kg (over 1100 kg per year). In the time of annual collection since 1987, the average annual yield of just over 400 kg.
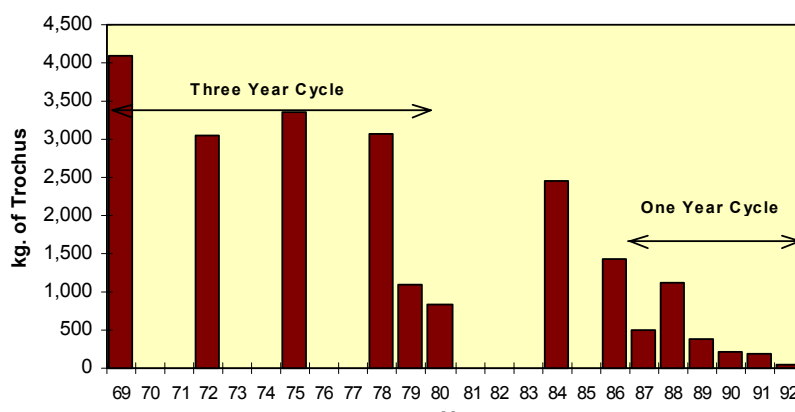

Figure IV.4 Yield of Trochus Shells in Noloth (Central Maluku, Indonesia) in 1969-1992 (source: data gathered from village head at Noloth, Maluku, as presented in Cesar et al. 1997).

Costs and benefits of overfishing in Indonesia are presented in Cesar (1996). He compares fisheries benefits in case of open access (OA) versus maximum sustainable yield (MSY) levels. He used data from Southeast Asia and the Pacific partly based on Munro & Williams (1985) and Alcala & Ross (1990). The latter describes an interesting case where protective fishery management was discontinued and where fishery yields dropped very quickly after resource access was re-opened. This is the same experience as in Hawaii where fisheries were re-opened after World War II with trophy catches during the first year. A comparison of fish standing stock in the Main Hawaiian Islands (heavily fished) versus the Northwest Hawaiian Islands (no fishing) also shows a dramatic difference (Friedlander & DeMartini, 2002). Cesar (1996) comes with an estimate in terms of net present benefit (10% discount rate; 25 year time horizon) of US$ 109,900 of the MSY and US$ 38.5 thousand in the case of OA for Indonesia.

Marine reserves: There is a growing body of literature suggesting that the establishment of marine reserves can be a sound management option in the light of overfishing. See for instance, Alcala (1988), White (1989), Alcala & Russ (1990), Polunin & Roberts (1993), Roberts (1995), Russ (1989, 1994). For a recent overview, see Rodwell & Roberts (2000). For instance, Alcala (1988) presents estimates of the island of Sumilon, where fish yields of 14-24 mt/km2/year have been reported before the sanctuary and where these catches increased to 36 mt/km2/year when the marine reserve was in place. Fish yields fell back to about 20 mt/km2/year when island management broke down. Most studies are unambiguous about the positive impact of marine reserves on reef fish abundance and size.

The "spillover" effect (increase in biomass outside the closed area) of closed areas is, however, complex and not yet well understood. It includes movements of both adults, juveniles and larvae, and the transfer mechanisms may be density-dependent (an effect from the closed area) or uni-directional (transport of larvae) (Rodwell & Roberts, 2000). The examples that potentially demonstrate the spillover effect are those of Apo Island in the Philippines and Kisite Marine National park in Kenya. Data from the Soufriere Marine Management Area in St. Lucia and Merritt Island National Wildlife Refuge in Florida confirm the predicted role of marine reserves in supporting fisheries outside the reserve areas (Roberts et al., 2001).

The most effective size, location and design of reserves have been and remain the subject of much discussion and research. Recent studies indicate that marine reserves, in order to be effective fisheries management and biodiversity conservation tools, will need to be established in large-scale networks covering significant portions of marine ecosystems (at least 10-20%) (Ballantine, 1995; Allison et al., 1998; Roberts et al., in press a, b; cited in Rodwell and Roberts, 2000). Roberts and Hawkins (in press; cited in Davis, 2000) detail the scientific arguments for setting aside at least 20% of the ocean as no-take zone. They write: "The main reasons for conservationists and scientists backing a target of 20% closure are: (1) this figure can be justified on the basis of the best biological information currently available; (2) such closures are expected to provide significant economic benefits to fisheries; (3) it is a realistic figure to implement. However, we shouldn't look upon 20% as a fixed goal, but rather as an average, with some areas and habitats needing less protection and others needing more." This is the same argument recently made for Hawaii (Birkeland & Friedlander, 2002).

Appendix V. Recreational diving industry

The role of the recreational diving industry is crucial in the management of the marine resources in Hawaii. On the one hand, the diving industry is an important beneficiary of Hawaii marine resources and thereby is largely dependent on its healthy condition. On the other hand, the diving industry themselves form a potential threat to the reefs by facilitating dive and snorkeling trips in these fragile ecosystems. In preparing an estimate of the economic value of the coral reefs in Hawaii and designing sustainable policies for management, it is of crucial importance to fully understand the functioning of this sector. Unfortunately, the last economic survey conducted on the diving industry dates back to the early 1990's. Tabata and Reynolds (1995) report on the developments and the configuration of the diving industry in 1990.

To fill this lacuna, a brief survey was conducted in late 2001 by SMS Research designed to give an estimate of the population of scuba divers and snorkelers in Hawaii. The survey was sent to 124 diving and snorkeling businesses around the state (addresses gathered from yellow pages, guide books, PADA website, and HIRSA website). Twenty-four surveys were returned as bad addresses. SMS remailed 19 surveys and refaxed 45 surveys two weeks later. Total response was 22 surveys.

This low response rate is an indication of the suspicion that lives among dive shop operators with regard to public inquiries. The Hawaiian diving industry can be characterized as a highly competitive and individualistic sector that is reluctant to collaborate in collective initiatives such as attempted by our study. Despite the relatively low response rate the results of the survey provide a rather good idea of the current status of the diving industry. After presenting the main conclusions of the study, a short summary is provided on the overall size of the industry in the early 1990s using the report by Tabata and Reynolds (1995) in order to derive an estimate of the present size of the market.

General description of the survey

As mentioned, 21 respondents returned the questionnaire to SMS. The results of the survey refer to the business in the year 2000. The island-wide distribution is shown in Figure V.5a. From the respondents 43% operated one boat, 36% of the entrepreneurs used two boats and 21% of the operators owned three boats for their operations. The majority of the respondents were in business already for more than 15 years.
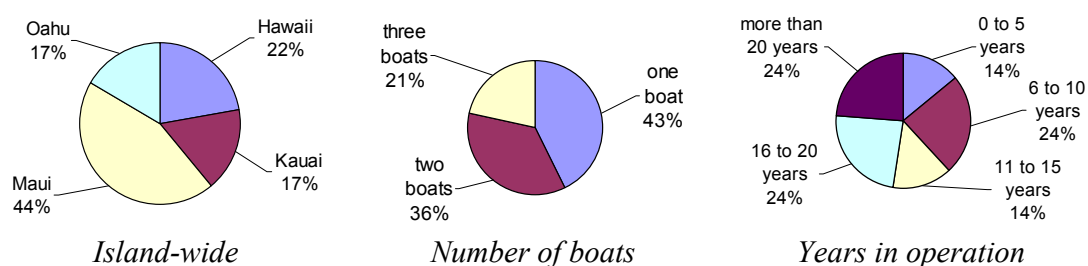

Island-wide   *Number of boats*   *Years in operation*

Figure V.5 General profile of the respondents

Table V.11 shows the main findings in terms of the size of operations. Clearly snorkeling serves most customers in the diving and snorkeling industry. Within the snorkeling business, organized tours by boat are far more popular than commercial trips from the shore. The last row of Table V.11 provides the average number of tours per operator for each type of activity.

Table V.11 Average size of operations

	Introductory scuba dive tours	Certified scuba dive tours	Snorkeling tours (by boat)	Snorkeling tours (from shore)
Total number of trips in 2000	20,124	34,179	70,651	3,243
Number of operators	16	18	13	7
Average number of trips per operator	1,258	1,899	5,435	463

Figure V.6 shows the average annual gross revenues of the responding dive and snorkel operators. Most operators earn between $200,000 and $400,000 per year. Obviously most of this revenues results from the sale of dive and snorkel tours. Besides providing dive and snorkeling tours, one of the main services of dive shops includes the filling of tanks for external customers. On average, each shop serves 387 customers each requiring 7 to 8 tank fillings per year. In other words, operators fill on average 3000 per annum.
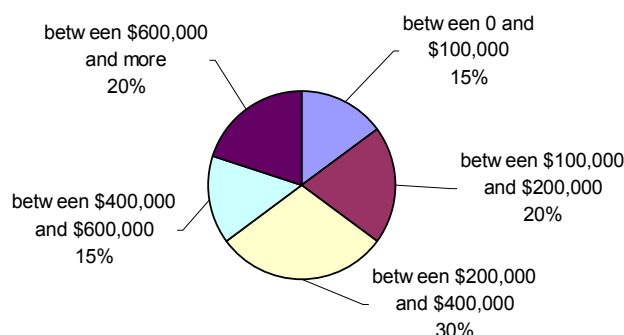

Figure V.6 Allocation of revenues of dive and snorkel operators

The customers

As shown in the last column of Figure V.7, most divers go on a two-tank dive (66%). The clientele of the dive operators originates mainly from the mainland. Hawaiians are particularly an important group of customers for the dive operations. Japanese come as the third most important category of clients. The proportional distribution of the clientele for divers and snorkelers does not significantly differ from that of the general visitors configurations of Hawaii.

Fuel consumption forms an important cost component for the operators. Therefore, their range of sites they can offer is generally constrained by travelling time and location. Several questions have been raised about the average travelling distance of the operators. On average, each dive operator travels 11 minutes over land and 21 minutes by sea to reach the average dive or snorkel destination.
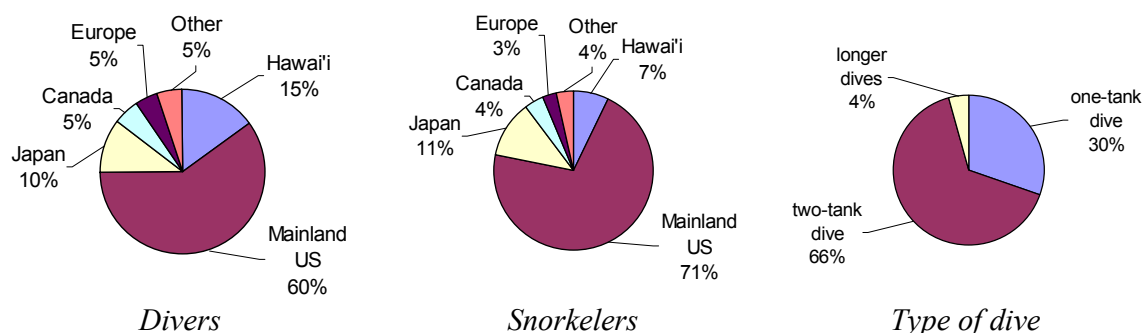
Divers *Snorkelers* *Type of dive*

Figure V.7 Distribution of country of origin of the clientele and the type of dive

Specific attention was raised in the survey to the sensitivity of the dive operators and the customers with regard to the ecological conditions of the marine environment. When asked whether half (or more) of the customers would be willing to travel farther -- and pay you for the travel -- to get to see more fish and healthier corals, 72% of the operators answered positively, while 28% of the respondents felt that the current travel time and costs was the maximum the customers would accept. In addition, Table V.12 indicates how the business development depends on the condition of the marine environment. The first column shows the expected growth without environmental improvements. The second column shows how, if environment improves, business will actually substantially benefit from it, indicating customers' sensitivity for environmental conditions.

Table V.12 Sensitivity of the dive industry for environmental improvements

		If conditions for marine life stay the same for the next five years, how will your business be affected?	*If conditions for marine life improve because of greater protection, how will your business be affected?*
a.	Improve a lot	9%	45%
b.	Improve some	32%	5%
c.	No change	36%	18%
d.	Get worse	23%	32%
e.	Get a lot worse	0%	0%

When asked about the importance of preferences of the average customers, the dive operators indicated that seeing turtles and dolphins are the most appreciated attraction of the dive and snorkeling tours. Second in preference are the diversity and abundance of fish encountered during the trips. Given the score of only 4%, corals are not considered to be a major attraction for divers and snorkelers in Hawaii.

Table V.13 Preferences of clientele according to the dive and snorkeling operators

	Importance
Swimming/diving where they can see turtles and dolphins	31%
Swimming/diving where they can see fish	24%
Information, education you provide about ocean life	13%
Simply getting out on the ocean	9%
Learning to snorkel/scuba	8%
Quality and safety of your equipment	7%
Swimming/diving where they can see coral	4%
Entertainment and food you provide	3%

The dive and snorkeling operators where also asked for their impression of the developments in environmental quality of the marine resources. An overwhelming majority of the respondents indicated that the marine environment has worsened in the last five years. Clearly, this has an impact on the general appreciation of their customers, given the fact that 68% is considered to be sensitive to environmental conditions (see Figure V.8).
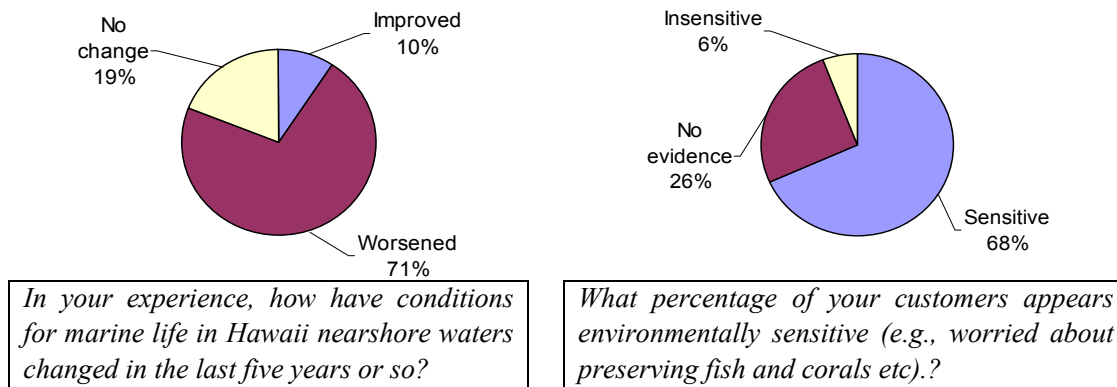

| In your experience, how have conditions for marine life in Hawaii nearshore waters changed in the last five years or so? | What percentage of your customers appears environmentally sensitive (e.g., worried about preserving fish and corals etc).? |

Figure V.8 Environment and environmental sensitivity of customers

The size of the market

The number of dives provided by the industry in the main four islands is provided in Table V.14. The main dive destination in Hawaii is Maui, followed by Big Island and Oahu. Kauai is still relatively less developed in terms of dive tourism.

Table V.14 Volume of the recreational diving industry for the different islands (in 1990)

	Number of introductory dives	Number of certified dives	Number of snorkeling tours	Number of certifications
Kauai	2,750	5,097	1,184	1,196
Oahu	13,500	15,388	423	6,407
Maui	20,500	41,467	78,395	4,355
Hawaii	7,000	18,752	47,795	928
Total	43,750	80,704	127,797	12,886

Source: Tabata and Reynolds (1995)

The Hawaii's recreational diving industry has grown substantially between the early 1980s and the 1990s. From estimated gross revenues of $7 million in 1982 the industry expanded to $19.8 million in 1986 and $26.9 million in 1990. Whereas 96 dive-related businesses were identified in 1990, over 130 were listed in 1994 by DBEDT Ocean Resources Branch.

There are three methods of deriving an estimate of the present size of the market for recreational diving and snorkeling. First, based on an average growth rate of the industry of 6 percent per year, the industry may presently have reached a volume between $55 and $60 million. Second, assuming a particular representation rate of the respondents in this survey (e.g. 18% for dive trips, 23% for snorkeling trips), the number of trips reported can be extrapolated fore the full number of operators in Hawaii and subsequently multiplied by the average rate for a dive or snorkeling tour. As shown in Table V.15 this leads to an estimate of $59 million. A third approach is to extrapolate the

reported revenues of each operator to Hawaiian wide levels. As shown in Table V.16 this approach leads to an estimate of approximately $63 million. Therefore it seems reasonable to assume the current volume of the industry to be around $60 million.

Table V.15 Estimate of the size of the dive and snorkeling market

	Introductory certification and dives	Certified scuba dive tours	Snorkeling tours from shore and boat	Other income (retail, tank filling, etc)	Total size of the market
Total trips respondents	52,173	34,179	73,894	-	160,246
Price per trip	$65	$65	$50	-	
Revenue respondents	$ 3,391,261	$ 2,221,635	$ 3,694,700	-	$ 9,307,596
Survey representation	18%	18%	23%		16%
Total trips market	289,851	189,883	328,418		
Revenue market	$18,840,340	$12,342,417	$16,420,889	$12,000,000	$59,603,646

Table V.16 Alternative calculation of the size of the dive and snorkeling market

	Alternative calculation
Average revenue	$634,266
Number of respondents	20
Total revenue	$11,416,782
Market representation	0.225
Total revenue	$50,741,254

Appendix VI. Snorkelers and divers survey

Little is known about the behavior and perception of divers and snorkelers in Hawaii. Tabata and Reynolds (1995) report on the diving industry in 1990 only from a macro perspective. What drives divers and snorkelers in Hawaii has never been systematically studied. To fill this lacuna, a survey was conducted in late 2001 and early 2002 by the survey bureau SMS Research.

Methodology

The target audience was the active user group of coral reefs in Hawaii. In total 50 divers and 260 snorkelers have been interviewed. In addition, 150 non-users conducted a short version of the interview to investigate differences in perception between users and non-users. In conjunction with Cesar Environmental Economics Consulting, SMS Research developed three nearly identical surveys that focused on individual divers' activities and contingent valuation of visits to the reefs. The three surveys included an internet survey, an airport intercept survey and a self administered survey that was delivered onsite. SMS Research was responsible for formatting the questionnaires. The internet survey was designed using SNAP software and put HTML by wincubic. Surveys were pre-tested and checked to make certain of accuracy of the completed forms.

This survey was fielded at 4 different locations: (a) internet (n=41), (b) Hanauma Bay, Oahu (n=152), (c) Maui (n=163), and (d) Honolulu Airport (n=103). The different versions of the survey had the same content. The internet survey was found at http://coralreef.smshawaii.com. All airport surveys and 55 Hanauma Bay surveys were fielded as an intercept survey, where an interviewer asks all the questions in the survey and fills out the answer. All Maui surveys and 97 Hanauma Bay surveys were self-administered, i.e., the respondents are handed surveys and fills it out themselves, and then return them to the interviewer.

Original plans called for the fielding for the individual diver survey to be conducted largely via the internet. Dive shops were to supply e-mail addresses to SMS, and we would then send links to the survey directly to respondents. However, the Hawaiian Islands Recreational Scuba Association board refused to support the survey, making the proposed procedures unworkable. Accordingly, the Internet survey was announced through Aloha Street.com (a Japanese language site for visitors to Hawaii) and personal networks. Additional fielding was done at the airport, Hanauma Bay, and dive sites on Maui.

Returned forms are opened and logged, then reviewed for completeness and condition. Blank forms and damaged forms are discarded. Data is then imputed by a data entry specialist and verified by the project director. The database is checked for internal consistency, missing or duplicate records, and improperly observed contingency items. Response options are checked for multiple answers, blank fields, and out-of-range codes. If any errors are found to have slipped by quality control procedures applied to thus point, response values are checked against the survey form to assure the proper information has been recorded. SMS developed the data set in SPSS version 9.0.

Survey results

Survey respondents were largely visitors to Hawaii (79%), of whom nearly 80% were from the US Mainland and 8% from Japan. Respondents included 257 (57%) who had gone snorkeling in Hawaii, 48 (11%) who had gone scuba diving, and 194 (42%) who had done neither. A quarter of the snorkelers and 44% of the scuba divers had enjoyed their sport elsewhere in the last year. Of those who had had an undersea experience, 51% had been at Hanauma Bay most recently, 24% were at Molokini or elsewhere on Maui, 15% had visited other Oahu sites, and a few others had visited the Big Island, Kauai, and Lanai. Figure VI.9 shows the motivations of the interviewed to come to Hawaii. Snorkeling and diving comes at the third place, after the obvious sun and sea expectations, and the more surprising cultural and historical motives of the visitors.
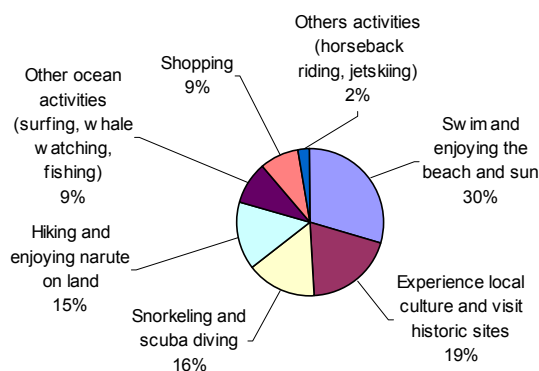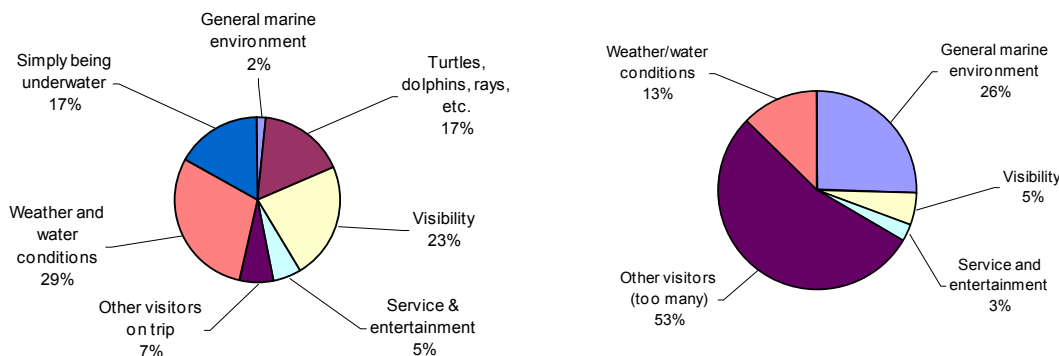

Figure VI.9 Relative importance of the various attractions to visitors

The divers dive on average 4.5 times and snorkelers snorkel on average snorkel 3.8 times during their stay in Hawaii. Some 94% of the snorkelers found their last experience in Hawaii enjoyable or very enjoyable, while 90% of the scuba divers did. However, only 77% of the snorkelers and divers were sure it was worth what they had paid. The reef users appreciate particularly the weather and water conditions (29%), the water visibility (23%) and seeing turtles, dolphins and other large fish (17%). When asked about their disappointments in relation to their snorkeling or diving activity, the majority (53%) indicated they disliked the massive scale of the operations. The groups were often found to be too crowded and often the behavior of fellow users were not appreciated. Also the general marine environment was seen as a concern (26%).

| What did you like most about your diving or snorkeling trip? | What did you dislike most bout your diving or snorkeling trip? |

Figure VI.10   Relative importance of the various attractions to visitors

Figure VI.11 shows the perception of the health status of the reef for different user groups. Clealry, the snorkelers are the least aware of the health irregularities of the Hawaiian coral reefs: 80% of those who had visited corals as snorkelers saw these as healthy or very healthy. The fact that 8% of the snorkelers do not know whether the coral reef is healthy or not indicates the general lack of knowledge of this user group. The divers are more pessimistic: 20% of the divers consider their sites as unhealthy or dead. As a cross group, active residents are the most critical user group: they judge that almost 30% of the reef is unhealthy or dead.

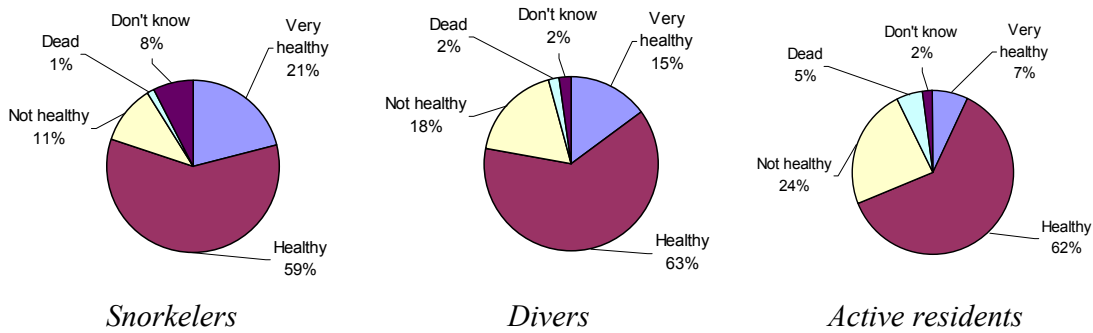| *Snorkelers* | *Divers* | *Active residents* |

Figure VI.11   How do the snorkeling and diving visitors and the snorkeling and diving residents qualify the health status of the coral reef they visited?

The survey contained an experiment that asked the respondents to look at the drawings depicted in Figure VI.12 and to pick the one that was most like the scene the respondent wants to experience offshore in Hawaii. The respondent was asked to subsequently indicate a first, second, and third choice. The first choice was awarded with 5 point, the second with 3 points and the third with 1 point. The overall ranking of the preferences of the different user groups – visiting divers, snorkelers, and active residents – is depicted below each drawing. Drawing A, which shows abundant but identical fish, is particularly popular among visiting divers and snorkelers. The active residents prefer to see a more divers marine environment and therefore chose drawing D as their most preferred scenery. The difference between drawing B and C is the presence of algae that overgrow the reef. Snorkelers appreciate this overgrowth, perhaps because it is seen as food for the turtle. Active residents and visiting divers, however, recognize the negative nature of the scene and therefore judge drawing C as undesirable.

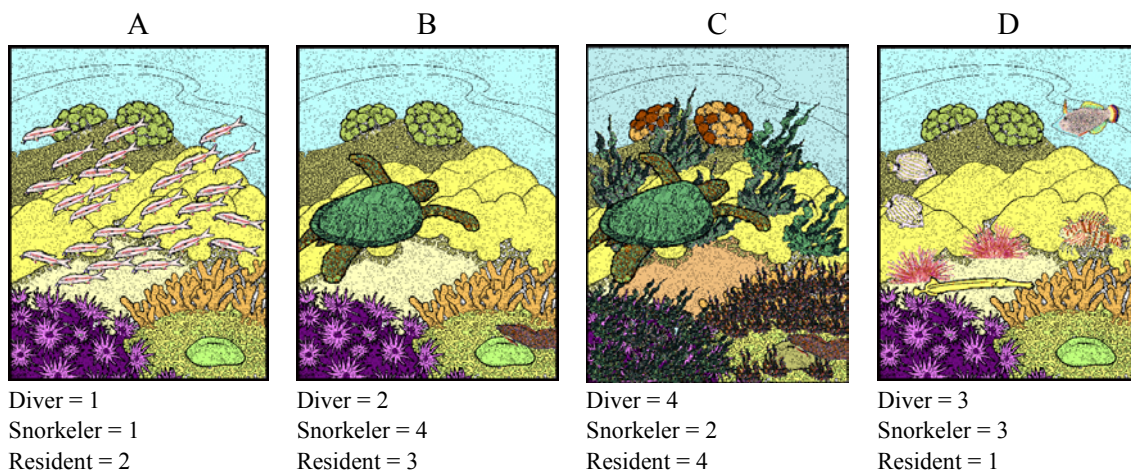| A	B	C	D
Diver = 1	Diver = 2	Diver = 4	Diver = 3
Snorkeler = 1	Snorkeler = 4	Snorkeler = 2	Snorkeler = 3
Resident = 2	Resident = 3	Resident = 4	Resident = 1

Figure VI.12   Ranking of the type of scenery the different groups of respondents prefer to experience offshore in Hawaii (1 is highest rank, 4 is lowest rank)

One of the main purposes of the survey was to determine the average profile of each user group in terms of actual expenditure directly attributable to the diving or snorkeling trip, the consumer surplus for this experience and the willingness to pay for a healthier marine environment.

To determine the consumer surplus for the actual experience, the following question was formulated. "*If everything -- fish, coral, water, the experience -- was the same, what do you think would be the maximum you would be willing to pay for that experience*?". Next the respondent was shown a card that contained the following options.

1 The amount you paid	7 $1 more than you paid
2 $1 less than you paid	8 $5 more than you paid
3 $5 less than you paid	9 $10 more than you paid
4 $10 less than you paid	10 $30 more than you paid
5 $30 less than you paid	11 $50 more than you paid
6 $50 less than you paid	99 DON'T KNOW/REFUSED

Then the respondent was asked to have a look at two sets of pictures (see Figure VI.13) and indicate which set of pictures was closer to what the respondent had experienced on the last dive or snorkel trip? Next, the following text was read to respondent "*Let's say the State of Hawaii had a marine life preservation program that protected corals, reef fish, and reef animals. This would help us have healthier coral and more marine life. The result would be like photo set A. Without this program, the reefs would look more like photo set B.*" Then the following question was read to the respondent "*With this program and with a healthier marine environment, what do you think would be the maximum you would be willing to pay for your scuba diving or snorkeling experience, including a fee for marine life preservation?*" The same payment card was shown to assist the respondent in selecting an amount.

Photo set A
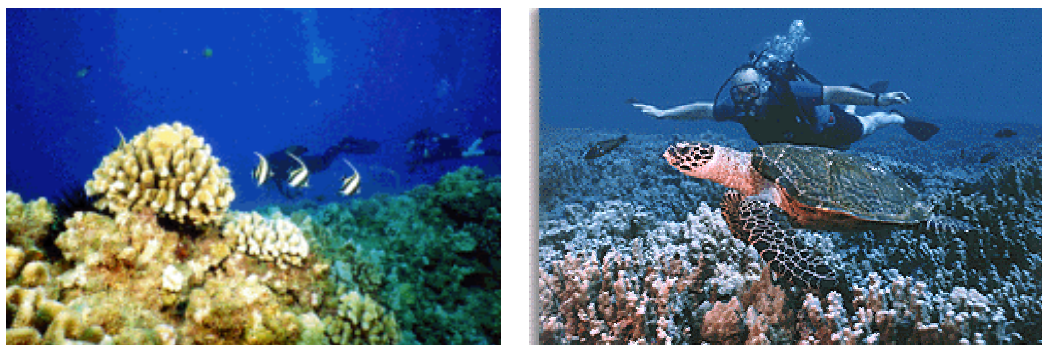
Photo set B
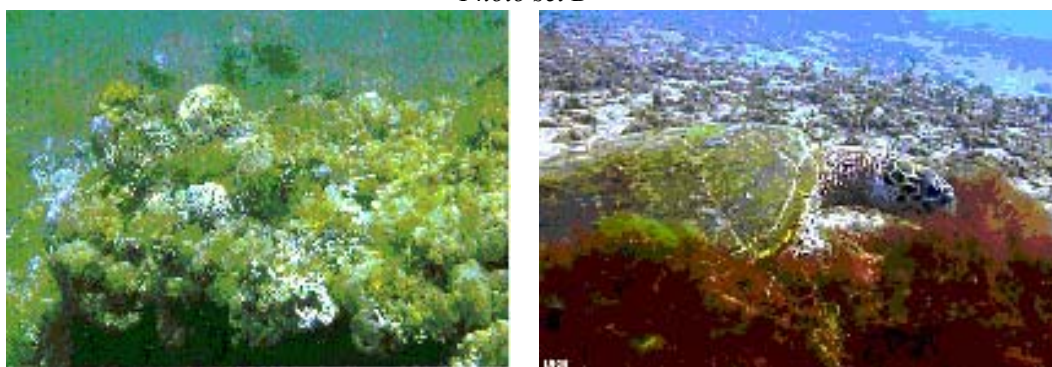
Figure VI.13   Representation of a healthy and an unhealthy reef in Hawaii

The results of this evaluation are shown in Figure VI.14. The real expenditures provide a predictable pattern. Residents generally spend much less on their dive or snorkel experience because they often have their own gear and also have less transportation costs to arrive at the site. The consumer surplus for the same experience, without any environmental changes, also is largely predictable. As shown in Figure VI.14 these are proportional to the real expenditures of the different user groups.

To determine the environmental component of the WTP question, the consumer surplus has been deducted from the additional WTP for a similar experience but than in a healthier marine environment. The surprising result is that the environmental component is much larger for the snorkeler ($2.69 per snorkeling trip) than for the diver ($0.44 per dive). In first instance one would expect the more advanced diver to have a higher WTP to protect the marine environment than the snorkeler. An explanation for this unexpected result is that the diver does already have high costs and therefore is less willing to increase its expenditures solely for the sake of marine conservation. Another explanation is that the diver, who is generally more acquainted with marine protection than the snorkeler, is more sceptic about the effectiveness of marine conservation programs. The resident has a relatively high willingness to pay for marine conservation ($2.86) most likely because they feel more affiliated to their own reefs than the visitors.
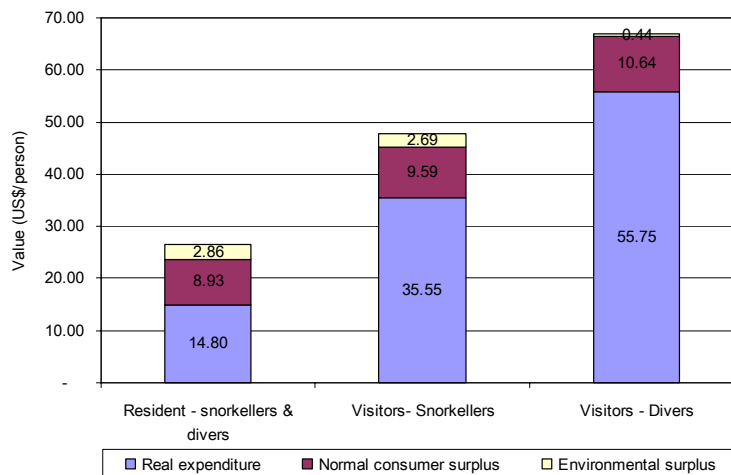

Figure VI.14   Allocation of real expenditures, consumer surplus for the same experience and the surplus payment for a better marine environment

Next, the interviewer asked the respondent whether it is reasonable to insist on scuba divers and snorkelers to pay a fee for marine life preservation. Only 22% of the respondents felt that it was not the responsibility of the users of the coral reef to keep it in a proper shape. They felt it was a typical responsibility of the state to do this. The majority of the respondents, however, felt that the divers and snorkelers should also, in one way or another, be held responsible for the costs of marine conservation, thereby supporting the polluter pays principle. Typically, when looking at the response of the subgroups it prevails that divers are more reluctant of taking responsibility than snorkelers. One of the reasons for this reluctance is that they perhaps feel that their contribution in the overall problem of reef degradation is limited.

To investigate this perception the respondents were asked who was responsible for degradation of Hawaii's coral reefs. As shown in Figure VI.15, a large proportion of the

respondents replied "Everyone." Others cited as responsible were, in order, tourists, developers, sewage treatment, the government, and divers and snorkelers.

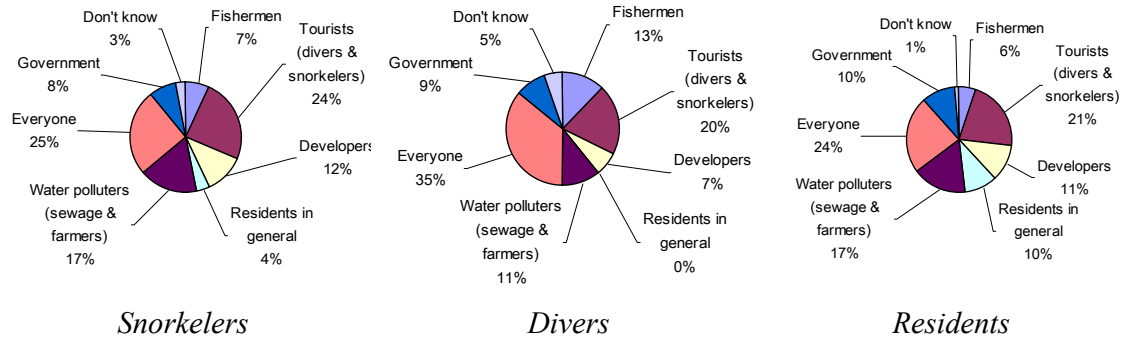*Snorkelers*   *Divers*   *Residents*

Figure VI.15   Assuming that the coral reefs naturally would be in a better condition, who is responsible for disturbing the natural state of the reefs of Hawaii?

Figure VI.16 shows how people responded to the question who was responsible for solving this problem. Most of those interviewed felt that responsibility for preserving the coral reef was everyone's business, although some placed the burden on the government.
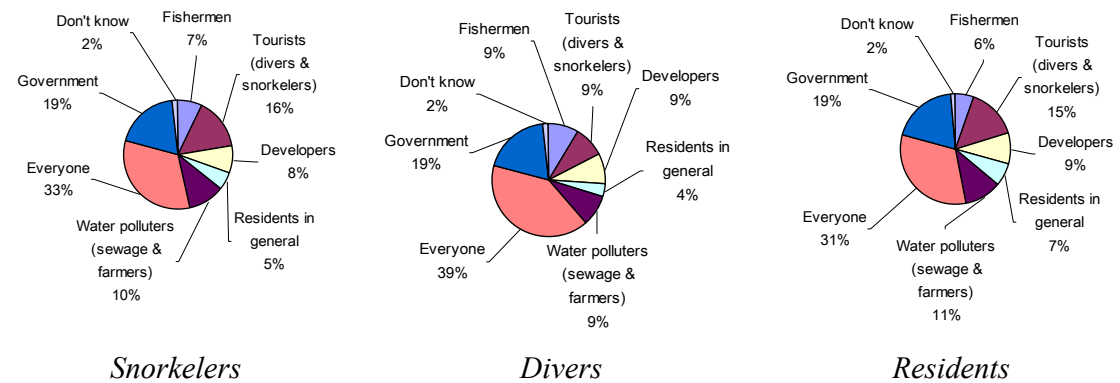

Snorkelers   *Divers*   *Residents*

Figure VI.16   Who is responsible for solving the problem of the disturbance the coral reefs of Hawaii?

Appendix VII. Travel costs method

Figure VII.17 shows the zonal distribution of visitors to the coral reefs of Hawaii in 2001 in ascending order of travel time. The zones are ranked according to travelling time. The regions of origin of the marine active tourists is divided into 14 zones with increasing distances from the point of departure of the visitor to the Hawaiian coral reefs. Visitation rates for zones are calculated and presented in Table 8.17. The visitation rates decrease dramatically with distance, from 7.81 per 1,000 of the population in the closest zone (US Pacific Coast), to 0.07 per 1,000 of the population in the most distant zone (Europe). The Pacific Coast has the highest visitation rate. This is understandable because this zone contains the largest number of marine active visitors a medium sized population.
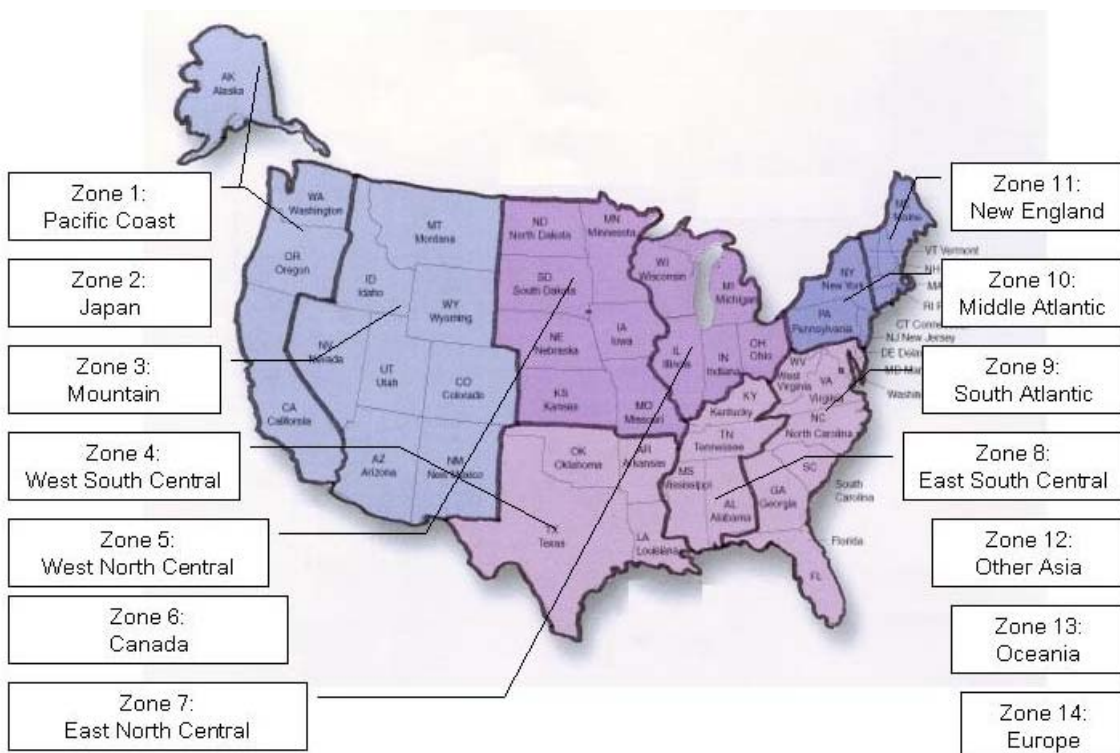

Figure VII.17 Zonal distribution of visitors to the coral reefs of Hawaii in 2001 (in descending order)

Next, the travel costs have been determined for the visitors from the different zones. Three type of travel-related costs are included: (1) the actual costs of transportation; (2) the costs related to the travel time; and (3) the local expenditures. Table 8.18 shows the results of this data collection exercise.

The transportation cost of visitors depends on the distance and means of transportation. Because most visitors to Hawaii come by plane, we simply measured the cost of a round trip economy ticket, not taking into account the distance travelled. Various economy rates of different air companies have been retrieved from the internet for the same period after which an average was drawn for each zone.

Table 8.17 Visitation Rate Per 1,000 of the Population Per Year for All Zones

Zone #	Zone name	Snorkelers/divers	Total population	Visitation rate / 1000
1	Pacific Coast	343,450	43,959,634	7.81
2	Japan	275,142	127,459,000	2.16
3	Mountain	70,208	18,727,904	3.75
4	West South Central	39,578	31,942,000	1.24
5	East North Central	68,069	45,370,000	1.50
6	Canada	39,051	31,500,000	1.24
7	West North Central	34,843	17,923,390	1.94
8	South Atlantic	56,941	51,461,367	1.11
9	East South Central	12,746	17,122,000	0.74
10	Middle Atlantic	43,211	39,771,000	1.09
11	New England	19,067	13,406,614	1.42
12	Other Asia	18,337	1,000,000,000	0.02
13	Oceania	14,608	23,000,000	0.64
14	Europe	22,684	302,640,000	0.07

Source: Calculated from survey data

Since time is a scarce resource and has an opportunity cost (i.e. time spent in one activity could be spent on another.), time needs to be included in the estimation of travel costs. Since the wage rate reflects the opportunity cost of time, it could be used as an approximate shadow price of time. However, the wage rate may be distorted by some institutional constraints. Therefore, appropriate ways to estimate the value of time have to be found. Deaton and Muellbauer (1980), cited by Hanley and Spash (1993), argued that if individuals are giving up working time in order to visit a site, the wage rate is the correct opportunity cost. However, most recreation time is spent at the expense of alternative recreational activity. This means the opportunity cost should be measured with reference to the marginal value of other recreation activities foregone.

Ideally, a separate value should, therefore, be calculated for each individual. However, collecting such information would be too complicated. Following Cesario as reported in OECD (1994) who suggested that the shadow price of time may lie somewhere between one-fourth and one-half of the wage rate, we assumed a wage rate of one-third of the actual wage rate of the visitors. To determine the wage rate we adopted the average income per zone on the basis of the divers and snorkelers survey. Time travelled was determined through an internet survey. Local spending was determined by multiplying the DBEDT estimate (2002) of daily expenditures times the length of stay of the visitors from the different zones. The variations between the individual zones is shown in Table 8.18.

Table 8.18   Total travel costs per visitor in 2001 (in US$ per visitor)

Zone #	Zone name	Travel costs	Travel time cost	Local spending	Total travel costs
1	Pacific Coast	425	88	1,337	1,849
2	Japan	560	65	1,362	1,987
3	Mountain	550	125	1,477	2,152
4	West South Central	600	113	1,300	2,013
5	East North Central	650	175	1,778	2,603
6	Canada	580	108	1,745	2,432
7	West North Central	575	163	1,435	2,172
8	South Atlantic	625	173	1,748	2,546
9	East South Central	660	156	1,693	2,509
10	Middle Atlantic	650	211	1,585	2,446
11	New England	700	217	1,946	2,863
12	Other Asia	875	131	2,799	3,804
13	Oceania	900	149	2,541	3,590
14	Europe	1,000	184	1,634	2,817

Source: DBEDT 202 and various airline courses on the internet

Next, the visitation rate estimated in Table 8.17 can be plotted against the total travel cost shown in Table 8.18. Not surprisingly, the plot in Figure VII.18 shows a pattern indicating a negative relationship between travel costs and the visitation rate. The Pacific Coast zone, which has the lowest travel costs also shows the highest visitation rate.
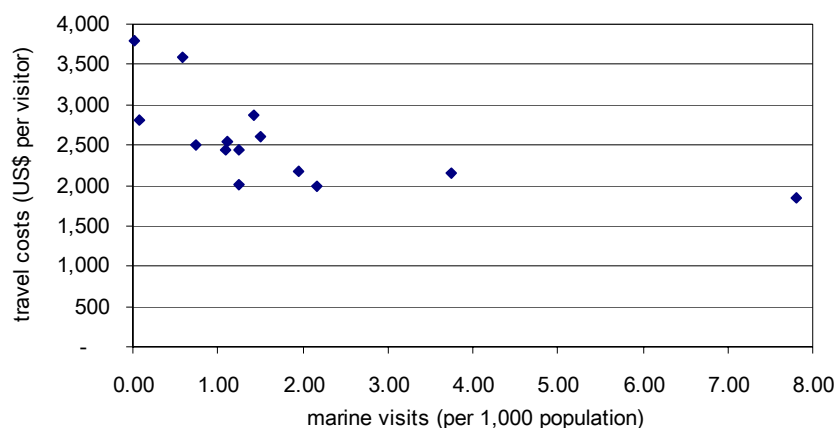

Figure VII.18   Graphical Relationship between the Visitation Rate and Travel Cost

To determine a demand curve from the above information, two approaches are often followed: linear regression and log linear regression. Since the visitation rate variable calculated violated the econometric assumption of normal distribution, the log of the visitation rate was used as a dependent variable in the demand function (see Strong, 1983; Smith, 1990 for a discussion). Equation 1 shows some results from the ordinary least square (OLS) regressions for zonal demand functions.

LN(visitation rate) = 5.172 – 0.00206 travel costs   (1)
(4.134) (-4.301)
$R^2 = 0.607$

Note: The t-statistics are in parenthesis and indicate that the variables are significant at a confidence level of 99%. The number of observations (zones) is 14.

Other specifications of the zonal demand equation with additional explanatory variables such as income and education did not give significant results for these variables. Therefore, the specification above was used for the estimation of consumer surplus. Equation (2) shows the general formula for consumer surplus (CS) based on a log-linear regression specified under Equation (1). For a more general specification with other explanatory variables, see Henderson et al. (2000).

$$CS = \sum_{i=1}^{14} \left\{ \frac{population_i}{\beta_1} \exp^{\beta_0} \left[\exp\left(\beta_1 P^*\right) - \exp\left(\beta_1 travel\, costs_i\right) \right] \right\} \qquad (2)$$

In this equation, the coefficients β_0 and β_1 are the estimates 5.172 and 0.00206 presented in Equation (1). The variable *population$_i$* is the total population of zone *i*. Finally, P^* is the choke Price. This is the price at which the quantity demanded of a natural resource is equal to zero. We assume a choke price for the total travel costs of \$3,805, or roughly twice the actual average costs per visitor. The choke price is theoretically defined as the price as which visitation is zero. However, with a log-linear specification, this price is not defined. Hence, the choke price is fixed at a level where the estimated zonal demand function becomes 'very close to zero'.

Figure VII.19 shows the user demand curve for visits to the Hawaiian reefs in the year 2001. The curve was drawn based on Equation (1). The user demand or marginal willingness to pay curve for Hawaii's recreational marine resources reflects a way of summarizing users' consumption attitudes and capabilities for such resources. This user demand curve is curvilinear and convex to the origin, that is, relatively flat at low prices and steep at higher prices. At low travel costs and high rates of visitation, relatively small increases in travel prices will lead to substantial reductions in the number of visits to the Hawaiian reefs. At high travel costs and low visitation rates, however, travel price increases have a much smaller effect and they produce much smaller reductions in the number of visits.
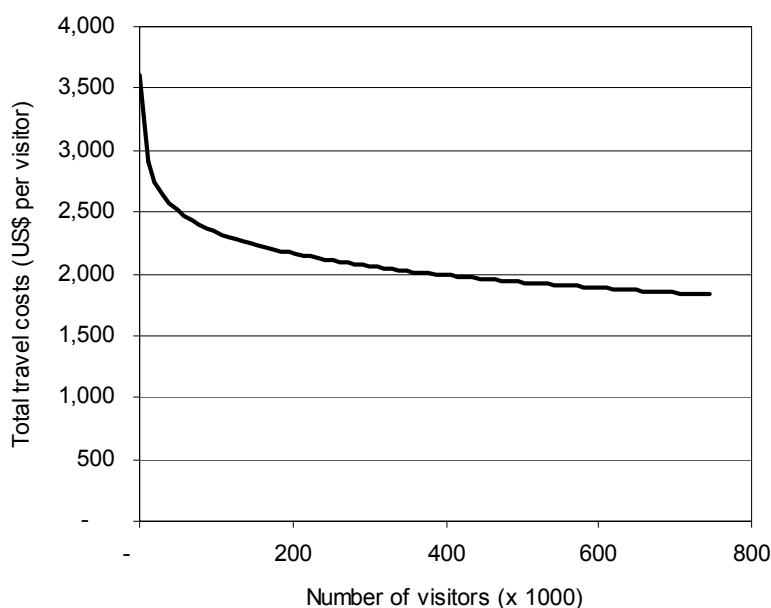

Figure VII.19   Graphical Relationship between the Visitation Rate and Travel Cost

From Equation (2), the consumer surplus per individual in each of the zones can be calculated. These are presented in Table 8.19. The numbers give the general consumer surplus of visitors to Hawaii based on the travel cost method. To capture the reef-associated consumer surplus, the consumer surplus per individual needs to be multiplied by the number of 'marine active tourists' and by the importance of reefs in their overall Hawaii experience. From the survey, it was determined that the latter was on average 18%, meaning that 18% of their expenditures could be attributed to coral reefs (see description of the survey in the Appendix). This leads to a total reef-associated consumer surplus of US$ 97 million.

Table 8.19   Consumer surplus of coral reefs in Hawaii in 2001 (in US$)

	Zone	Number of marine active visitors	Consumer surplus per marine active visitor	Reef associated consumer surplus per marine active visitor	Gross reef associated consumer surplus for Hawaii
1	Pacific Coast	343,450	398	72	24,602,286
2	Japan	275,142	802	144	39,726,853
3	Mountain	70,208	283	51	3,578,862
4	West South Central	39,578	1,312	236	9,349,236
5	East North Central	68,069	537	97	3,366,125
6	Canada	39,051	322	58	2,263,521
7	West North Central	34,843	190	34	2,322,476
8	South Atlantic	56,941	381	69	874,687
9	East South Central	12,746	239	43	2,453,058
10	Middle Atlantic	43,211	350	63	2,723,424
11	New England	19,067	65	12	223,710
12	Other Asia	18,337	1	0.1	2,064
13	Oceania	13,528	7	1	17,392
14	Europe	22,684	1,419	255	5,795,292
		1,056,853			97,298,986

The estimate of consumer surplus based on travel costs can be compared with the user-based contingency valuation estimate, presented in Table 8.2. The CVM estimate was $ 133 million. The TC and CVM estimates are relatively close ($97 million versus $133 million). This allows us to use the CVM figure for estimation of the Total Economic Value below.

Appendix VIII. Snorkelers and divers questionnaire

Hello, I'm _____ with SMS Research, a Hawaii research company. We need your help to learn more about how people appreciate the marine environment. We're not selling anything; we're only interested in your opinions. Everything you tell us will be 100% confidential. Would you be willing to participate in this survey?

[IF NO, ASK:] Are you greater than 18 years old? [IF NO, THANK AND TERMINATE. IF YES, CONTINUE]

Fill each applicable answer, fill completely or mark with "X"

Q1 Are you a resident of Hawaii?
    1 Yes [Skip to Q5]
    2 No
    99 DON'T KNOW/REFUSED [skip to Q5]

Q2 Please tell us a little about why you came to Hawaii on your most recent trip. Did you come to do or enjoy ONE THING -- so much that you would not have come to Hawaii if you could not do it?
    1 Yes
    2 No [skip to Q4]
    99 DON'T KNOW/REFUSED [skip to Q4]

Q3 The reason I came to Hawaii was: [MARK ONLY ONE CHOICE]
    1 Business
    2 Seeing friends or relatives
    3 A wedding
    4 Shopping
    5 Sightseeing on land
    6 Enjoying the beach and sun
    7 Whale watching
    8 Fishing
    9 Seeing tropical fish, coral reefs, turtles or dolphins
    10 Scuba diving
    99 DON'T KNOW/REFUSED

Q4 When you decided to go to Hawaii, what activities did you expect to be the valuable and satisfying parts of your trip to Hawaii? [MARK ALL THAT APPLY]
    1 Enjoying the beach and sun
    2 Swimming
    3 Surfing, body surfing, windsurfing
    4 Visiting historic or cultural sites
    5 Shopping
    6 Meeting people from Hawaii
    7 Hiking
    8 Going to Volcanoes National Park or the top of Haleakala
    9 Seeing the land and nature on land (forests, gardens)
    10 Seeing tropical fish, coral reefs, turtles, or dolphins
    11 Scuba diving
    12 Whale watching
    13 Fishing
    14 Jet Skiing, parasailing, hang gliding, flying or gliding

15 Riding horses
16 Dancing or seeing Hawaiian dance
99 DON'T KNOW/REFUSED

Q5 Have you gone on scuba dives in Hawaii in the last 12 months?
1 Yes
2 No [Skip to q12]
99 DON'T KNOW/REFUSED [Skip to q12]

Q6 How many dive trips have you taken in Hawaii in the last 12 months?
1 One
2 Two to five
3 Six to ten
4 Eleven to twenty
5 More than twenty
99 DON'T KNOW/REFUSED

Q7 Have you gone on scuba dives elsewhere in the last 12 months?
1 Yes
2 No
99 DON'T KNOW/REFUSED

Q8 How many times have you gone scuba diving in Hawaii in the last 12 months?
1 One
2 Two to five
3 Six to ten
4 Eleven to twenty
5 More than twenty
99 DON'T KNOW/REFUSED

Q9 Was your most recent scuba dive in Hawaii: [READ CHOICES]
1 Very enjoyable
2 Enjoyable
3 Not very enjoyable, not unpleasant
4 Unpleasant
5 Very unpleasant
99 DON'T KNOW/REFUSED

Q10 What did you like most about your last scuba dive in Hawaii? [READ CHOICES]
1 The general marine environment (fish, coral)
2 Turtles, dolphins, sharks and/or rays
3 How well you could see in the water
4 The service or entertainment on the trip
5 Other visitors who took the trip with you
6 The weather and water conditions
7 Being underwater
8 Other_____
99 DON'T KNOW/REFUSED

Q11 What did you dislike most about your last scuba dive in Hawaii? [READ CHOICES]
1 The general marine environment (fish, coral) (For example, not seeing many fish)
2 Turtles, dolphins, and/or rays (not seeing these)
3 How well you could see in the water
4 The service and entertainment on the trip

    5 Other visitors who took the trip with you
    6 The weather and water conditions
    7 Being underwater
    8 Other _____
    99 DON'T KNOW/REFUSED

Q12 Have you gone snorkeling in Hawaii in the last 12 months?
    1 Yes
    2 No [Skip to Q18]
    99 DON'T KNOW/REFUSED [Skip to Q18]
[If Q5 and Q12 are both NO or "DON'T KNOW/REFUSED then skip to Q28]

Q13 How many times have you gone snorkeling in Hawaii in the last 12 months?
    1 One
    2 Two to five
    3 Six to ten
    4 Eleven to twenty
    5 More than twenty
    99 DON'T KNOW/REFUSED

Q14 Have you gone snorkeling elsewhere in the last 12 months?
    1 Yes
    2 No
    99 DON'T KNOW/REFUSED

Q15 Was your most recent snorkeling trip in Hawaii: [READ CHOICES]
    1 Very enjoyable
    2 Enjoyable
    3 Not very enjoyable, not unpleasant
    4 Unpleasant
    5 Very unpleasant
    99 DON'T KNOW/REFUSED

Q16 What did you like most about the last snorkeling trip you took in Hawaii: [READ CHOICES]
    1 The general marine environment (fish, coral)
    2 Turtles, dolphins, sharks and/or rays
    3 How well you could see in the water
    4 The service and entertainment on the trip
    5 Other visitors who took the trip with you
    6 The weather and water conditions
    7 Being underwater
    8 Other_____
    99 DON'T KNOW/REFUSED

Q17 What did you dislike most about the last snorkeling trip you took in Hawaii: [READ CHOICES]
    1 The general marine environment (fish, coral) (For example, not seeing many fish)
    2 Turtles, dolphins, sharks and/or rays
    3 How well you could see in the water
    4 The service and entertainment on the trip
    5 Other visitors who took the trip with you
    6 The weather and water conditions
    7 Being underwater
    8 Other _____
    99 DON'T KNOW/REFUSED

Q18 On your last dive or snorkel trip were corals and reefs you visited mostly: [READ CHOICES]
    1 Very healthy
    2 Healthy
    3 Not healthy
    4 Dead
    99 DON'T KNOW/REFUSED

Q19 Where was your last dive or snorkel trip? [READ CHOICES]
    1 Hanauma Bay
    2 Waikiki area
    3 Other Oahu sites
    4 Molokini
    5 Other Maui sites
    6 Kauai
    7 Big Island
    8 Lanai
    99 DON'T KNOW/REFUSED

[Before Q20, show drawing card #1] [Each answer "A" "B" "C" "D" may be used only once]
Q20 Please look at some drawings. Please pick the one that is most like the scene you want to experience offshore in Hawaii, then your second choice, then the third choice:

		A	B	C	D
20A	First Choice	1	2	3	4
20B	Second Choice	1	2	3	4
20C	Third Choice	1	2	3	4

    99 DON'T KNOW/REFUSED

Q21 Please tell us: In the last month, when you last went snorkeling or scuba diving in Hawaii, how much did you spend on
A) Snorkeling trips. $_____
B) Scuba diving trips. $_____
C) Snorkel or scuba gear $_____
D) Souvenirs, etc. related to your underwater experience $_____
    99 DON'T KNOW/REFUSED

Q22 Now, please think about your most recent snorkeling or diving experience: How much did you pay for it? $_____
    99 DON'T KNOW/REFUSED

Q23 Was it worth what you paid?
    1 Yes
    2 No [Skip to Q25]
    99 DON'T KNOW/REFUSED

Q24 If everything -- fish, coral, water, the experience -- was the same, what do you think would be the maximum you would be willing to pay for that experience? [READ CHOICES]…
    1 The amount you paid
    2 $1 more than you paid
    3 $5 more than you paid
    4 $10 more than you paid
    5 $30 more than you paid
    6 $50 more than you paid
    99 DON'T KNOW/REFUSED

Q25 If everything -- fish, coral, water, the experience -- was the same, what do you think would be the maximum you would be willing to pay for that experience? [READ CHOICES]

    1 The amount you paid
    2 $1 less than you paid
    3 $5 less than you paid
    4 $10 less than you paid
    5 $30 less than you paid
    6 $50 less than you paid
    99 Don't know/REF

Before Q26, show picture card #2
Q26 Please look at the two sets of pictures [SHOW THE TWO SETS OF PICTURES]. Which of these is closer to what you experienced on your last dive or snorkel trip?

    1 Set A
    2 Set B
    99 DON'T KNOW/REFUSED

Let's say the State of Hawaii had a marine life preservation program that protected corals, reef fish, and reef animals. This would help us have healthier coral and more marine life. The result would be like photo set A. Without this program, the reefs would look more like photo set B.

Q27 [ASK IF Q23 IS YES] With this program and with a healthier marine environment, what do you think would be the maximum you would be willing to pay for your scuba diving or snorkeling experience, including a fee for marine life preservation? [READ CHOICES]

    1 The amount you paid
    2 $1 more than you paid
    3 $5 more than you paid
    4 $10 more than you paid
    5 $30 more than you paid
    6 $50 more than you paid
    99 DON'T KNOW/REFUSED
  [ALL ANSWERS: SKIP TO Q28]

Q27A [ASK IF Q23 IS NO] With this program and with a healthier marine environment, what do you think would be the maximum you would be willing to pay for your scuba diving or snorkeling experience, including a fee for marine life preservation? [READ CHOICES]

    1 The amount you paid
    2 $1 less than you paid
    3 $5 less than you paid
    4 $10 less than you paid
    5 $30 less than you paid
    6 $50 less than you paid
    7 $1 more than you paid
    8 $5 more than you paid
    9 $10 more than you paid
    10 $30 more than you paid
    11 $50 more than you paid
    99 DON'T KNOW/REFUSED

Q28 Is it reasonable to ask scuba divers and snorkelers to pay a fee for marine life preservation? [READ CHOICES]

    1 Yes, they enjoy their trips, and benefit from the preservation effort
    2 Yes, everyone should pay for this good cause
    3 Yes, visitors to our marine areas have a special responsibility to future generations

4 Yes, Other reason_____
5 No, this is not something the state should be doing
6 No, this is not something that scuba divers and snorkelers should have to pay for
7 No, Other reason_____
99 DON'T KNOW/REFUSED

Q29 Who do you think is responsible for any unhealthy or poor reef conditions in Hawaii?
 1 Fishermen
 2 Divers and snorkelers
 3 Developers
 4 Tourists
 5 Residents in general
 6 Sewage treatment
 7 Farmers
 8 Everyone
 9 Government
 99 DON'T KNOW/REFUSED

Q30 Who do you think should be responsible for preserving coral reefs and marine life in Hawaii?
 1 Fishermen
 2 Divers and snorkelers
 3 Developers
 4 Tourists
 5 Residents in general
 6 Sewage treatment
 7 Farmers
 8 Everyone
 9 Government
 99 DON'T KNOW/REFUSED

The remaining questions are for statistical purposes.

Q31 Where do you live?
 1 Mainland US
 2 Canada
 3 Europe (including United Kingdom)
 4 Japan
 5 Asia (including Philippines)
 6 Elsewhere
 99 DON'T KNOW/REFUSED

Q31A[ASK IF Q31 IS MAINLAND US] Please specify zip code:
 99 DON'T KNOW/REFUSED

Q32 Have you ever lived in Hawaii?
 1 Yes
 2 No [Skip to Q34]
 99 DON'T KNOW/REFUSED

Q33 For how long?
 1 Less than a year
 2 A year to four years
 3 Five or more years
 99 DON'T KNOW/REFUSED

Q34 Do you have Native Hawaiian ancestry?
    1 Yes
    2 No
    99 DON'T KNOW/REFUSED

Q36 What is your age? ____Years old
    99 DON'T KNOW/REFUSED

Q37 What is your highest level of education completed?
    1 Did not finish high school
    2 High school
    3 Some college or university
    4 Finished college (bachelor's degree)
    5 Advanced degree
    99 DON'T KNOW/REFUSED

Q38 Please tell me about your household income last year. Was it: [SHOW CARD#3]
A   1 $25,000 or less
B   2 $25,000 to $50,000
C   3 $50,000 to $75,000
D   4 $75,000 to $100,000
E   5 Over $100,000
F   99 Prefer not to answer

That's all the questions I have. One last thing: Just in case my supervisor needs to verify that I did this survey, may I have your first name and your phone number, please?
Name:_____ Phone #: (   ) _____
email:_____fax #:_____

THANK YOU VERY MUCH FOR PARTICIPATING IN OUR SURVEY.

        Thank you very much for your help. Mahalo nui loa!