Economic Valuation of the Coral Reefs of Hawai'i[1]

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Abstract: Hawai'i's coral reef ecosystems provide many goods and services to coastal populations, such as fisheries and tourism. They also form a unique natural ecosystem, with an important biodiversity value as well as scientific and educational value. Also, coral reefs form a natural protection against wave erosion. Without even attempting to measure their intrinsic value, this paper shows that coral reefs, if properly managed, contribute enormously to the welfare of Hawai'i through a variety of quantifiable benefits. Net benefits are estimated at $360 million a year for Hawai'i's economy, and the overall asset value of the state of Hawai'i's 1660 km^2 (410,000 acres) of potential reef area in the main Hawaiian Islands is estimated at nearly $10 billion.

ABOUT 85% OF (the potential) reef area of the United States is within the Hawaiian Archipelago. The majority of this area is located in the Northwestern Hawaiian Islands (8521 km^2 or 2.1 million acres). The main Hawaiian Islands have 2536 km^2 (627,000 acres) of potential reef area, with 1660 km^2 (410,000 acres) under the jurisdiction of the State of Hawai'i (see Table 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 Hawai'i 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.

Although the coral reef area of the main Hawaiian Islands is smaller, its economic importance outweighs that of the coral reef area of the Northwestern Hawaiian Islands. For example, the annual number of visitors to the main islands is 11 million, but the Northwestern Islands receive only 5000 visitors per year. Because of this substantial contrast and the large differences in data availability, in this paper we focused solely on the main Hawaiian Islands.

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

In Hawai'i, the traditional *ahupua'a* concept considered 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.

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TABLE 1

Summary of Data of the Hawaiian Islands

Island	Land Area (km^2)	Reef Area (km^2) 0–3 Nautical Miles	Reef Area (km^2) 3–200 Nautical Miles	Total Reef Area (km^2)
Main Hawaiian Islands				
Hawai'i	10,433	252	0	252
Maui	1,884	270	0	270
O'ahu	1,546	504	0	504
Kaua'i	1,431	266	0	266
Moloka'i	673	128	870	998
Remaining main Hawaiian Islands	660	236	10	246
Total main Hawaiian Islands	16,627	1,656	880	2,536
Northwestern Hawaiian Islands	15.4	2,430	6,091	8,521
Total Hawaiian Archipelago	16,642	4,086	6,971	11,057

Source: Gulko et al. (2002).

Economic valuation can help to revive the Hawaiian *ahupua'a* concept of ecosystem integration. It does this by highlighting the costs of ignoring interdependencies. It can therefore play a crucial role in communicating the importance of reefs to Hawai'i's people and policy makers. Moreover, economic valuation helps with natural resource damage assessment (for instance, in case of oil spills, ship groundings, human-induced sedimentation, etc.). Finally, it can provide an economic basis for financial commitments by the state and federal governments for coral reef management (see also Van Beukering and Cesar 2004, in this issue). In this light, our objective in this paper is to assess the economic value of the coral reefs of the state of Hawai'i.

MATERIALS AND METHODS

In the paper by Van Beukering and Cesar (2004) in this issue, the SCREEM model (Simple Coral Reef Ecological Economic Model) for Hawai'i is explained. This model links ecology and economy in a dynamic manner. SCREEM 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 nonrenewable resources (sand, etc., from mining of reefs). The services of coral reefs include: (1) physical structure services, such as coastal protection; (2) biotic services, both within ecosystems (e.g., habitat maintenance) and between ecosystems (e.g., biological support through mobile links); (3) information services (e.g., climate record); and (4) social and cultural services, such as aesthetic values, recreation, and gaming. For a full description of these goods and services, see Moberg and Folke (1999) and Costanza et al. (1997).

Each of these goods and services has associated net economic benefits. The value of the sum of compatible uses of these goods and services form the total economic value of coral reef ecosystems (e.g., Spurgeon 1992). This total economic value 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 1, the total economic value of coral reef ecosystems consists of use and nonuse values. Use values come from net benefits that arise from the actual use of the ecosystem, both directly and indirectly, such as fisheries, tourism, and beachfront property. Nonuse 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,

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 1. Subdivision of the total economic value of coral reefs.

amenity and property values, research, and biodiversity. These values combined give a "lower boundary" estimate of the total economic value.

For recreational benefits, both consumer surplus and producer surplus values need to be considered (see also Pearce and Turner [1990] or any other textbook in environmental economics). Figure 2 shows the conceptual composition of the reef-related recreational benefits. The supply curve for recreation is positively sloped because more dive and snorkel trips are supplied at higher levels of revenue. The demand curve is negatively sloped because the demand is high at low prices and will drop if prices increase. Demand and supply match at the equilibrium indicated by *e*, which is a combination of price *p* and *q* number of tourists that will engage in snorkeling or diving.

Both producers and consumers benefit from the availability of snorkeling and dive opportunities. In fact, the consumers as a group would have been willing to pay as much as the area *ceq0* but instead are only paying as much as *peq0*. The difference between these two is the consumer surplus, depicted in the graph as the shaded triangle *cep*. The consumer surplus is defined as the price that tourists would be willing to pay for their recreational activity over and above what they

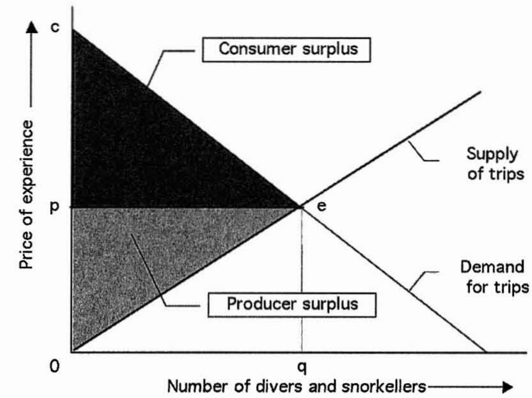

FIGURE 2. Conceptual composition of the recreational benefits.

actually spend. 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* in revenues. Their net benefit, referred to as producer surplus, is equal to the shaded triangle *pe0*. The recreational value of coral reefs in Hawai'i is approximated by the sum of the consumer and the producer surplus (for a more in-depth discussion as well as caveats, see Pearce and Turner [1990]).

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 is available to value these ecosystem goods and services. Those used in this study are the effect on production, replacement costs, damage costs, travel costs, and the contingent valuation method. For a description of these methods applied to coral reefs, see Barton (1994) and Cesar (2000). For a general description, see Pearce and Turner (1990).

Effect on production 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. Replacement costs 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. Damage costs use the value of expected loss of the "stock at risk" as a straightforward proxy for the value of the coastal protection service. Travel costs are 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. The contingent valuation method solicits information through questionnaires about the willingness to pay for various environmental goods and services and/or willingness to accept for their loss/degradation.

It is too costly to obtain all relevant data through original data collection for the whole of Hawai'i. Therefore, field data in one site are sometimes used for other, comparable, areas for which no such field data are available, and data on a selected number of sites are extrapolated to larger areas. This is allowed, if the areas are comparable and as long as the extrapolation is done carefully. This practice of using monetary values obtained in one area for another area that lacks such values is called "benefit transfer."

Using these different techniques, annual quantitative numbers for these different goods and services can be determined. With the initial data, the SCREEM model computes the trends over time of these annual figures (see Van Beukering and Cesar 2004, in this issue). The annual data over time are used to obtain the value of a good or service. For instance, for fisheries, annual benefits and costs are determined. To convert these annual fisheries figures into values, the net present value of fisheries benefits minus the associated costs are calculated. The net present value is defined as the aggregated discounted value over time at a given discount rate and for a specific time horizon (T). The formula is given in the following equation:

$$\text{net present value} = \sum_{i=0}^{T} \frac{\text{benefit}_i - \text{cost}_i}{(1 + \text{discount rate})^i}$$

For a general discussion on net present values and on discounting as applied to environmental economics, see Freeman (1993).

Data for the various benefits and costs of tourism/recreation, fisheries, amenity values, and biodiversity for Hawai'i have been obtained from a number of different secondary data sources as well as from specific surveys under this research project. The sources, surveys, and results have been described in detail in Cesar et al. (2002). The various data are as follows:

(1) Tourism data were obtained through: (a) a dive shop survey, to estimate the magnitude of the scuba and snorkel industry; (b) a tourist survey, in which 50 divers and 260 snorkelers were interviewed regarding their perception of different types of coral habitats, their willingness to pay for coral reef management, and their travel and holiday costs; and (c) official Hawai'i tourism statistics. These data are given in Cesar et al. (2002).

(2) Amenity values were based on data obtained from a survey of real estate and the

hotel and condominium business in Hawai'i under this project. Properties close to a healthy marine environment are more valuable than comparable properties elsewhere, because of better views and better coastal protection. To accurately capture these value differences is a complex exercise that requires an enormous amount of information. Ideally, these reef-related attributes of property value are estimated with the hedonic pricing method applied to general property prices. Due to resource limitations, this was 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 beachfront level of residential, condominium, 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, condominium, and hotel properties. Background to these calculations is given in Cesar et al. (2002).

(3) Fisheries data have been obtained through: (a) official statistics of the Division of Aquatic Resources (DAR) of the State of Hawai'i; (b) a fisheries survey for aquarium fisheries along the Kona coast on the island of Hawai'i; and (c) a review of the published literature on reef fisheries. A total of 12,273 t of commercial marine landings were recorded in 2001, of which 2.7% is reef-associated in value terms. With an area of 2536 km^2 of reefs (i.e., potential coral reef area in both state and federal waters of the main Hawaiian Islands [Gulko et al. 2002]), this gives an average yield of 0.1 t per square kilometer per year.

(4) Two components of the biodiversity value relevant for Hawaiian reefs are distinguished: the research value and the nonuse value. The research value is determined in a rather straightforward manner. All research budgets assigned to coral reef ecosystems in Hawai'i are included in this value category. Non-use values express people's willing to pay some money amount for a good or service they currently do not use or consume directly.

TABLE 2

Estimated Number of Dives and Snorkeling Trips in Hawai'i in 2001 (Thousands of Trips)

Type of Visitor	Snorkeling Trips[a]	Dives
Residents	1,240	370
U.S. West	5,570	170
U.S. East	3,860	120
Japan	1,550	135
Canada	610	20
Europe	440	15
Other	1,370	40
Total	14,640	870

[a] Includes both organized and unorganized snorkeling experiences.

RESULTS

Reef-Related Recreation

To calculate the recreational benefits of the Hawaiian reefs, several steps were taken. First, we identified the number of recreational users of the coral reefs of Hawai'i. Obviously, not all visitors go snorkeling or diving. 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 under water. By combining this information with the overall visitor numbers, a rough estimation can be made of the number of snorkel and diving trips conducted in Hawai'i (see Table 2). 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. These two numbers appeared to match rather well.

The next step in calculating the recreational value of Hawaiian reefs involved a determination of the annual monetary value attributed to each marine activity, based on the SCREEM model. We took into account four categories (see Table 3).

(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

TABLE 3

Recreational Value of Coral Reefs in Hawai'i in 2001 (in Million $)

	Consumer Surplus	Value Added of Direct Expenditure	Value Added of Indirect Expenditure	Multiplier Effect	Total Value Added
Snorkelers					
Residents	10.1	2.3	—	0.6	13.0
U.S. West	47.8	20.9	23.1	11.0	102.9
U.S. East	33.2	14.5	20.4	8.7	76.8
Japan	13.3	5.8	2.2	2.0	23.4
Canada	5.2	2.3	3.6	1.5	12.6
Europe	3.8	1.7	2.2	1.0	8.7
Other	11.8	5.1	6.8	3.0	26.7
Subtotal	125.2	52.6	58.4	27.8	264.0
Divers					
Residents	3.4	5.1	—	1.3	9.9
U.S. West	1.6	3.1	3.5	1.7	10.0
U.S. East	1.1	2.2	3.1	1.3	7.7
Japan	1.3	2.5	2.7	1.3	7.8
Canada	0.2	0.3	0.5	0.2	1.3
Europe	0.1	0.3	0.3	0.1	0.9
Other	0.4	0.8	1.0	0.5	2.7
Subtotal	8.1	14.3	11.3	6.4	40.2
Total recreational value					
Residents	13.5	7.5	—	1.9	22.8
U.S. West	49.4	24.0	26.7	12.7	112.8
U.S. East	34.3	16.7	23.6	10.1	84.6
Japan	14.6	8.3	4.9	3.3	31.1
Canada	5.4	2.6	4.1	1.7	13.9
Europe	3.9	1.9	2.6	1.1	9.6
Other	12.2	5.9	7.8	3.4	29.4
Total	133.3	66.9	69.7	34.2	304.2

actual payment to enjoy the Hawaiian reefs experience. This estimate of $133 million is based on contingent valuation method estimates from the tourism survey (see Cesar et al. 2002). Also, a travel costs calculation was carried out in the same survey to compare travel costs and contingent valuation estimates (Cesar et al. 2002). The travel costs and contingent valuation method estimates are relatively close ($97 million versus $133 million). This allowed us to use the contingent valuation method figure as the consumer surplus.

(2) The actual expenditures directly related to the snorkeling or diving experience. This includes entry fee, hiring of mask and fins, bus fare, and so forth. These expenditures estimated with our survey questions are discussed in detail in Cesar et al. (2002). We assumed that 25% of these expenditures can be considered as value added: $67 million. This is the producer surplus of services directly attributable to diving and snorkeling.

(3) The expenditures indirectly related to the marine experience such as hotel costs and travel costs. The Department of Business, Economic Development, and Tourism (2002) reported that marine activities such as diving and snorkeling form 18% of the total motivation of visitors to come to Hawai'i. Using this 18% and survey estimates of total indirect expenditures and assuming again only a portion of these expenditures as value added, gave the value added of indirect expenditures ($70 million). As before, it was assumed that only 25% can be considered as value added for the Hawaiian economy for hotel and other expenditures. For airfare, this percentage value added was assumed to be 2%.

(4) The multiplier effect of 1.25 for the

TABLE 4

Property Value Within One Block (100 m) of the Coastline in Hawai'i in 2001 (Billion $)

Type	O'ahu	Maui[a]	Hawai'i	Kaua'i[a]
Condominium	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 O'ahu and Hawai'i 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 condominium property values.

TABLE 5

Annual Reef-Related Property Value in Hawai'i in 2001

Type of Property	Total Value Hawai'i Property (in Million $)	Reef-Related Value (in Million $)	Share of Total Value (%)
Condominium	2,237	7	0.30
Residential	13,846	21	0.15
Hotels	5,587	13	0.23
Total	19,498	40	

Hawaiian economy (Department of Business, Economic Development, and Tourism 2002). The resulting number of $34 million is based on the actual expenditures and not on consumer surplus.

These four categories combined give the current annual recreational value of the Hawaiian coral reefs for snorkelers and divers ($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 the sheer number of snorkelers compared with divers.

Beachfront Property and Amenities

To transfer the property values for O'ahu and the island of Hawai'i to Maui and Kaua'i we used resident numbers in 2001 for residential properties and visitor numbers in 2001 for hotel and condominium property values. Table 4 shows the property values within 100 m of the coast of the main Hawaiian Islands in 2001 based on our analysis. It is not surprising that property values for O'ahu outweigh those of the other islands. Both property value and population density are much higher on that island.

On the basis of the expert judgment of real estate agents we assumed that 1.5% of the sale price of the properties is attributable to the marine ecosystem. In addition, we valued this component only at the actual selling of the property. The frequency with which condominiums, residential houses, and hotels change ownership was assumed to be every 5, 10, and 6.5 yr, respectively. The annual reef-related property value of the four main Hawaiian islands is shown in Table 5.

Fishery Value

Because of the lack of good estimates for subsistence and recreational fisheries and for the actual coral reef area, the only option was to use DAR statistics. Furthermore, we assumed average fish prices of $5 per kg and a value added percentage of 60%, in line with those reported in Kona (Cesar et al. 2002). Finally, we used a multiplier of 40% for fisheries. This gives a total reef-associated fishery benefit of $1.3 million per year (Table 6).

Biodiversity Value

To determine the biodiversity value a brief survey was conducted. All potential research candidates were asked to provide their annual budget for 2001. Table 7 shows the list of research projects and organizations that are involved in one way or another in reef-related research. The sum of these activities amounted to $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.

As described in Materials and Methods, nonuse values are based on the fact that peo-

TABLE 6

Annual Reef-Related Fishery Value in Hawai'i in 2001

Species Group	Quantity (t)	Total Value (Million $)	Reef Dependency (%)	Reef-Associated Fishery Revenue (Million $)	Reef-Associated Fishery Benefit (Million $)
Tuna	6,393.8	31.0	0	0	0
Billfish	2,882.8	12.5	0	0	0
Misc. pelagic	1,540.8	5.8	0	0	0
Deep bottomfish	329.9	2.4	0	0	0
Akule/'Ōpelu	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	12,273.6	55.9	2.7	1.5	1.3

Source: Division of Aquatic Resources (2001) web site and our own calculations.

TABLE 7

Hawaiian Coral Reef–Related Research Funds Allocated in 2001 (in $)

Research Source	Amount
1. Calibration support for Hawaiian reef mapping	73,809
2. Assessment of invasive introduced microalgae in Hawai'i	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. U.S. Geological Survey reef structure and environmental history	60,000
7. U.S. Geological Survey reef structure and environmental history	98,000
8. U.S. Geological Survey continuation of reef stratigraphy and evolution	34,040
9. U.S. Geological Survey South Moloka'i marine investigations coral reef biologic component	76,367
10. Hanauma Bay carrying capacity	100,000
11. Hawai'i 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. Geographic Information System 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. Department of Aquatic Resources	400,000
21. Aquarium	2,300,000
22. Coastal Zone	170,000
23. School of Ocean and Earth Science and Technology, University of Hawai'i	1,325,950
24. Social Science Research Institute, University of Hawai'i	900,000
Total value	10,445,765

ple are willing to pay some money amount for a good or service that they currently do not use or consume directly. In the case of the Hawaiian coral reefs, people who are not current visitors 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.

Spurgeon (1992) indicated two factors, representing the supply side and the demand side, that have a substantial impact on

TABLE 8

Calculation of Nonuse Value for Hawaiian Reefs in 2001 (in $)

Region	Total No. of Households in Region	Share of Households with Nonuse Value (%)	No. of Households with Nonuse Value	Willingness to Pay	Total Nonuse Value
Hawai'i residents	400,000	100	400,000	$10	$4,000,000
Visitors	113,000,000	1	1,130,000	$3	$3,390,000
Total value					$7,390,000

Source: Willingness to pay estimates from Leeworthy and Wiley (2000:59).

the magnitude of the nonuse 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 reefs are unique because of the presence of a large number of endemic species, but on the other hand they are not special because of the relatively limited number of species.

(2) The size of the population, and their level of environmental awareness, is positively related to nonuse values. This demand-side factor implies that the Hawaiian reefs are in relatively great nonuse demand. Most reefs in the world are located in developing countries and therefore have a rather poor and uneducated audience.

To determine the nonuse value for the Hawaiian reefs we adopted the approach used by Leeworthy and Wiley (2000). In their study for the Tortugas Ecological Reserve they calculated a nonuse value assuming that 1% of the U.S. population would be willing to pay for the reserve. They applied three values, $3, $5, and $10 per household per year. From our own survey we found that the involvement of Hawai'i residents with coral reefs is very high. Therefore we assumed that for this group all households would be willing to pay $10 per year. For the remaining group, the visitors, 1% have a nonuse value of the lower amount, $3 per household per year. This results in a total nonuse value of $7.4 million per year (Table 8).

Total Economic Value

Combining the annual figures for tourism, amenities, fisheries, and biodiversity presented here and/or in Cesar et al. (2002) and estimating the future trend in these figures allowed us to determine the overall economic value of the coral reefs of Hawai'i. To do so required 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 Hawai'i. However, because the reef types vary greatly and the types of threats are so diverse, no Hawai'i-wide intervention in coral reef management can be defined. Therefore, we assumed that the benefits remain constant over time. The time period considered is 50 years. The results are presented at a discount rate of 3%; however, to demonstrate the impact of this selection a sensitivity analysis for a range of discount rates was performed.

Table 9 shows the composition of the main economic benefits of the coral reefs in Hawai'i. 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. This is the total quantifiable asset value of reefs in Hawai'i.

Without discounting this value would be nearly $19 billion, and at a discount rate of 15% the net present value amounts to $2.8 billion (Cesar et al. 2002). These high numbers indicate that it is certainly worthwhile, both from an ecological and an economic

TABLE 9

Annual Benefits and Net Present Value of Hawaiian Coral Reefs and the Different Study Sites

Types of Value	Units	Value
Recreational	Million$/yr	304
Amenity	Million$/yr	40
Biodiversity	Million$/yr	17
Fishery	Million$/yr	2.5
Total annual benefits	Million$/yr	363.5
Net present value (3% discount rate)	Million$	9,700

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 reefs of Hawai'i. 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 Hawai'i 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 nonuse value of the Hawaiian reefs, on the other hand, is estimated on the basis of a rather simple approach and is therefore a candidate for improvements. A current NOAA-funded study is under way to assess the nonuse values of coral reefs in Hawai'i. Typically, the fishery value is the least important reef-related benefit.

DISCUSSION

In this article we present the first published work on economic valuation of coral reefs in Hawai'i. The tourism value as well as the amenity value, biodiversity value and fishery value have all been used for the total economic value.

Regarding fisheries, Munro (1984) presented estimates of a sustainable harvest of edible finfish and invertebrates of 15 t/km^2/yr. Yields for each of these vary significantly. Russ (1991) summarized 11 studies on yields of small coral reefs with estimates ranging from 0.42 to 36.9 metric tons of reef fish per km^2 per year. According to Russ (1991), the difference 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 of reef fishing. Russ (1991) quoted an example of a yield estimate of 24.9 t/km^2/yr when the area estimate is based on a maximum depth of 60 m. With a 20-m maximum, the yield would have been 48.79 t/km^2/yr. A depth of 40 m is often taken as a standard. On the basis of these considerations, Russ (1991) suggested that sustainable yields on the order of 10–20 t/km^2/yr are feasible for small areas of actively growing coral reef. This is in line with McAllister (1988), who assumed sustainable yields of 18 t/km^2/yr for reefs in excellent condition, 13 t/km^2/yr for reefs in good condition, and 8 t/km^2/yr 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 t/km^2/yr.

The official harvest for Hawai'i as recorded by DAR is very low compared with the figures from the published literature on reef fisheries given here. There are four explanations: (1) overfishing is severe; (2) coral reef areas in Hawai'i are less productive than corresponding reef areas in Southeast Asia because they are quite far from the epicenter of marine biodiversity (Indonesia/Philippines/Papua New Guinea) where the estimates presented in Russ (1991) came from; (3) recreational and subsistence fishery is large in Hawai'i and this is not included in the commercial yield statistics; and/or (4) the definition of coral reef area in the official statistics of Hawai'i is of "potential" reefs up to 100 m depth, implying that this potential reef area may be considerably larger than the actual reef area. It is likely that all four factors are quite important in explaining this difference.

The fact that coral reefs have tremendous value often seems to elude policy and decision makers. If these decision makers were more aware of the amount of capital that healthy reefs can bring to the economy in terms of tourism, fisheries, and biodiversity among others, a more concerted and united management effort would probably be initiated. Economic valuation can help to ensure that coral reefs are properly taken into account in public decision making and that financial resources, both state and federal, are made available for their management and conservation. In addition, economic valuation enables the assessment of monetary losses to the economy when reefs are damaged as a result of human activities (e.g., ship groundings, oil spills, sedimentation).

The annual net benefits derived from the coral reefs of Hawai'i have been calculated here at $360 million a year for Hawai'i's economy, and the overall asset value of the state's 1660 km^2 (410,000 acres) of potential reef area is estimated at nearly $10 billion. This is a conservative estimate of the actual economic value because no attempt was made to estimate the intrinsic value of these reefs beyond their actual uses.

With more data and additional analysis, these estimates can be improved further. In fact, more research on the noneconomic values of coral reefs in Hawai'i is very much needed. This may imply that some of the numbers need to be adjusted in the future. However, the central message that the Hawaiian coral reefs are an extremely valuable resource and that this value will grow over time if properly managed will not change. The people of Hawai'i know this, and in fact, the traditional *ahupua'a* management system was based on this understanding. We hope these economic numbers can help policy makers understand this as well.

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