The economic value of Guam's coral reefs

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Abbreviations

Abbreviation		*Definition*
BSP	=	Bureau of Statistics and Plans
CPUE	=	Catch Per Unit Effort
CBA	=	Cost Benefit Analysis
CVM	=	Contingent Valuation Method
DAWR	=	Division of Aquatic and Wildlife Resources
DCE	=	Discrete Choice Experiment
FY	=	Fiscal Year
GEPA	=	Guam Environmental Protection Agency
GIS	=	Geographical Information System
GVB	=	Guam Visitors Bureau
MARC	=	Micronesian Area Research Center
MPA	=	Marine Protected Area
N/A	=	Not Applicable
NPV	=	Net Present Value
TCA	=	Travel Cost Approach
TEV	=	Total Economic Value
TNC	=	The Nature Conservancy
VAT	=	Value-added tax
WPRFMC	=	Western Pacific Regional Fishery Management Council
WTP	=	Willingness to Pay

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Executive summary

The coral reef ecosystems of Guam are unique. Despite its limited size, the island possesses fringing reefs, patch reefs, submerged reefs, offshore banks, and a barrier reef surrounding its southern shores (Figure E.1). The reef margin varies in width, from tens of meters along some of the windward areas to well over hundreds of meters (Hunter, 1995). More than 1,000 fish species inhabit Guam's coral reefs (Myers and Dondaldson, 2003). These fish play key roles in the ecology of the reefs and have been an important food source since people first settled on Guam (Amesbury and Hunter-Anderson, 2003).

In May 1997, the Guam Government adopted a resolution declaring the importance of maintaining the health and stability of coral reef ecosystems (Underwood, 1997). As such, it was formally recognized that coral reefs are deeply woven into almost every aspect of the lives of Guam's citizens. Healthy coral reefs are vital to Guam's economy, which is largely driven by the tourism industry. At the same time, coral reefs are also an important element in the island's culture. Moreover, the reefs provide natural coastline protection against high waves, storm surges and coastal erosion, especially during typhoons and tsunamis.

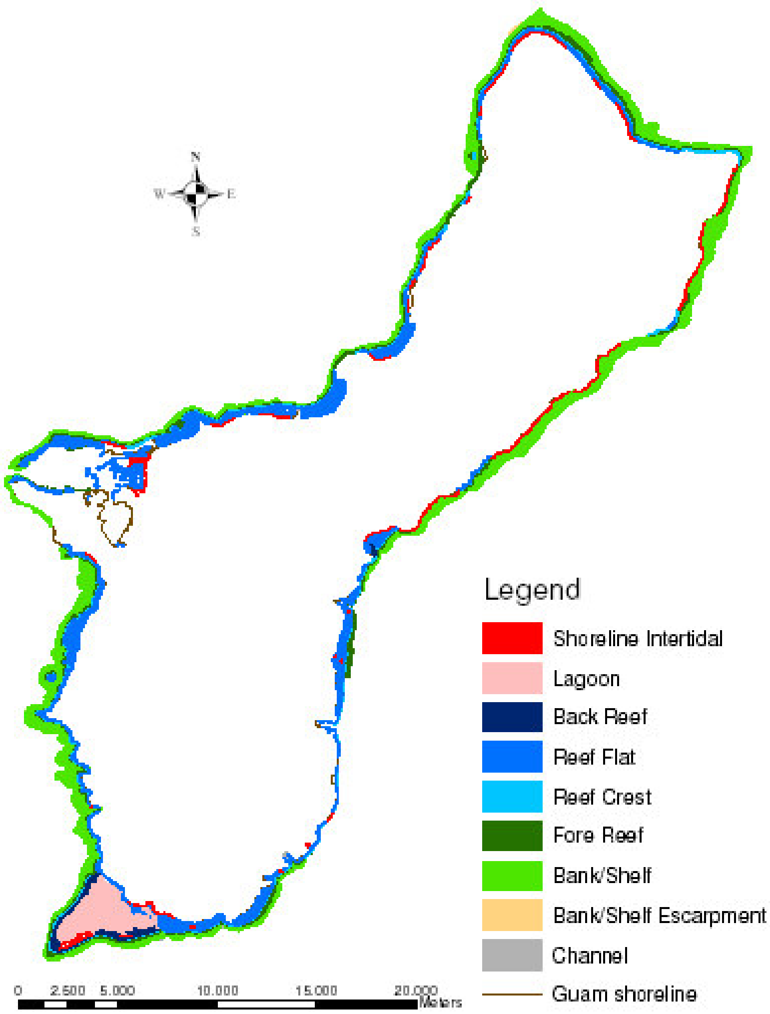


Figure E.1 The coral reefs of Guam (source: NOAA habitat maps NCCOS, 2005)

Despite this formal recognition of reefs' importance to Guam's economy, many human activities are still causing the degradation of reefs and the wider marine environment. Guam's reefs are especially threatened by sewage outfalls, runoff, sediment, silt, and environmental stresses caused by an increasing number of visitors. The rapid economic development driving these threats will ultimately lead to significant degradation of Guam's reef, which in turn will negatively affect many economic sectors in Guam. Due to the lack of knowledge on the economic importance of Guam's coral reefs, the magnitude of such potential damage remains unclear.

Measuring the extent of coral reefs' economic importance in Guam is not a straightforward exercise. Earlier attempts concluded that the ecological services, tourist-related industries and coastal protection function of Guam's reefs were worth US$85 million per year (Richmond, 2000). This estimate, however, was mainly based on secondary data sources and is therefore not necessarily accurate. Moreover, it excludes the cultural importance of reefs, which can also be expressed in monetary terms.

The objective of this study was to carry out a comprehensive economic valuation of the coral reefs and associated resources in Guam. The focus was on valuing the five main uses of coral reefs in Guam. Some of these are extractive uses, such as fisheries (i); others are non-extractive, such as recreation/tourism (ii), cultural/traditional uses (iii), and education and research (iv). Finally, some are indirect uses, such as shoreline and infrastructure protection (v). With a better understanding of the economic importance of coral reefs, Guam's decision makers can formulate more effective policies utilizing limited funds.

The valuation of Guam's coral reefs involved a series of steps that ultimately led to the estimation of the total economic value. At the same time, we uncovered the underlying motives and mechanisms that lie behind this value. In particular, we focused on (1) people's relationships with marine ecosystems; (2) local willingness to pay for coral reef conservation; (3) the economic importance of Guam's reefs; and (4) the spatial variation of reef-associated values and threats.

People's relationships with marine ecosystems

The main purpose of the household survey (of 400 local residents) was to determine the nature and level of the cultural value of coral reefs. The survey covered a number of issues, such as respondents' level of beach and marine recreation, environmental awareness, fishing activities and the importance of fish in their diet.

Recreation: Several recreational activities link local residents to marine ecosystems. Almost everybody in Guam has barbeques, swims or wades at the beach (Table E.1). Nevertheless, only a minority can actually swim. A significant share of respondents also participates in snorkeling and diving. Clean, clear and safe water, and good public facilities were considered to be the most important recreational amenities in Guam. Coral reefs and fish abundance were also mentioned as relevant, but were not considered to be crucial amenities.

Table E.1 Recreational activities in Guam

Rank	Activity	Days per household/year	Share of active respondents
1	Swimming/wading	17.01	87%
2	Beach picnic/barbeque	13.26	92%
3	Fishing	9.05	45%
4	Snorkeling	7.40	44%
5	Kayaking/paddling	2.73	21%
6	Scuba diving	2.65	19%
7	Body boarding/ surfing	1.75	12%
8	Jet skiing	1.73	14%
9	Windsurfing/ kiteboarding	0.25	5%

The dietary importance of fish: Despite external influences, freshly-caught fish is still an essential and healthy part of local diets. Most households consume fish approximately twice a week. This has not changed a great deal in the last decade. However, presently more than half of all consumed fish comes from stores or restaurants, while around 40% comes from immediate or extended family or friends.

Environmental awareness: Most local residents have witnessed a degradation of the marine environment in recent decades, in particular a decline in both water quality and fish abundance. This is not surprising, given that these are the most relevant marine elements for local residents, and elements on which the media focuses greatest attention. Residents were also relatively well-informed about the potential causes of marine degradation. They identified three main causes: increased runoff, poor development practices and leakage from broken sewage pipes (Table E.2). When asked for solutions, local residents called for improvements to the sewage system, enhancement of environmental education and stricter law enforcement.

Table E.2 Perception of causes of environmental change in Guam's marine environment

Rank	Perceived cause of environmental degradation	Importance
1	Increased runoff and storm water	20.7%
2	Sedimentation due to poor development practices	20.6%
3	Leakage from broken sewage pipes	18.4%
4	Use of improper fishing methods (gillnets, fishing with scuba gear)	9.5%
5	Increased pesticide/fertilizer outflows from golf courses and hotels	7.6%
6	Sedimentation due to intentionally lit fires	6.3%
7	Too many fishermen	5.7%
8	Too many jet skis, banana boats	5.1%
9	Too many divers and snorkelers	1.9%
10	Other, specify …	4.2%

Note: The score represents the average importance that residents give to each of the proposed causes of environmental change in the marine ecosystems of Guam.

Fishing: Between 35% and 45% of respondents were active fishermen. On average, fishermen go fishing around once a week. Despite the depleted fish stocks, fishing has not declined in popularity. In fact, because fishermen have grown older and have more time available, they now go fishing more frequently. The most popular techniques include: i) hook and line fishing at shallow depths, ii) trolling, and iii) spear fishing with snorkeling gear. Despite their destructive nature, gillnetting and spear fishing with scuba gear are still practiced.

The majority of fishermen fish because it strengthens social bonds and because they enjoy it. On average, fishing costs fishermen around US$165 per month. Only a minority of fishermen in Guam sells part of their catch and earns around US$250 per month doing so. In other words, fishing in Guam is neither a subsistence nor a commercial activity.

Main lesson of the survey: Outside influences have not fully disconnected local residents from the ocean. Albeit to a lesser extent than in the past, residents of Guam still use the marine environment for fishing and recreational activities. As such, people are concerned about further deterioration of the marine environment, and they support policy interventions that aim to reverse this negative trend. In fact, they have clear ideas about the direction in which these policies should move. This was an important and encouraging finding of the survey.

Local willingness to pay for coral reef conservation

Guam's coral reefs provide important cultural, recreational, and non-commercial fishery values that are not easy to measure using traditional economic methods. Individuals may value or enjoy various aspects of the reef or services it provides but may never have to pay directly or indirectly for these benefits. Furthermore, these non-market values may be difficult to define and harder yet to quantify. However, it is extremely important to include non-market values in economic assessments to ensure that governments and policy makers are aware of the full value associated with natural assets such as coral reefs.

The Discrete Choice Experiment: To estimate these non-market values, the Discrete Choice Experiment (DCE) was used. The DCE is a stated preference research method that forces respondents to repeatedly choose between complex, multi-attribute profiles which describe various changes in non-market benefits at a given cost (e.g. a change in tax paid). For each choice set, a respondent evaluates the alternatives and chooses a preferred option. The alternative options in each choice set are described using a common set of attributes, which summarize the important aspects of the alternatives.

The DCE is an efficient means of collecting information, since choice tasks require respondents to simultaneously evaluate multi-attribute profiles. Economic values are not elicited directly but are inferred by the trade-offs respondents make between monetary and non-monetary attributes. As a result, it is less likely that Willingness to Pay (WTP) information will be biased by strategic response behavior.

Finally, and perhaps most importantly in the context of non-market valuation, choice experiments allow individuals to evaluate non-market benefits described in an intuitive and meaningful way, without being asked to complete the potentially objectionable task of directly assigning dollar figures to important values such as culture.

The DCE for Guam: The discrete choice experiment implemented for this research project investigated three important non-market benefits associated with Guam's coral reefs: local recreational use, abundance of culturally significant fish species, and non-commercial fishery values. In addition, a pollution attribute and a reef fishery management attribute were also included in the choice experiment as two factors affecting reef health. Income tax was included as the monetary variable in the choice experiment to provide a suitable payment vehicle for willingness to pay calculations (Figure E.2).

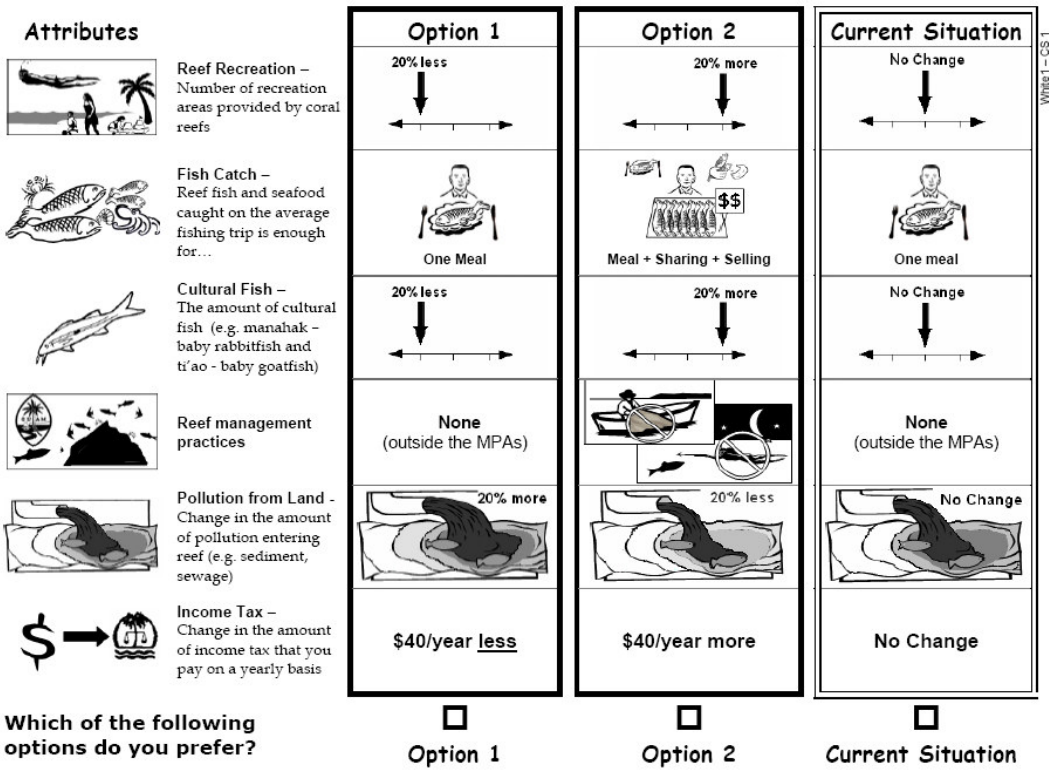


Figure E.2 Example of a choice set used for the DCE in Guam

Value of non-use benefits: The results of the DCE indicate that significant economic values are associated with the three non-market benefits included in the survey. Guam's residents appear to place a similar value on the reefs' ability to provide local recreational benefits and supply culturally significant fish species. In addition, the results indicate that maintaining reef fish and seafood stocks at a level that can support the culture of food sharing is very important. One other interesting result emerged. The WTP for sufficient fish catches to share with family and friends was valued at US$92 per fisherman. Typically, if the fish catch was big enough so as to also allow for the sale of fish, the WTP dropped to US$32. This negative value associated with the sale of fish implies that the sharing of fish is significantly more important than earning additional income.

Attitude towards management: Although Guam's residents generally support a ban on some of the more exploitative fishing methods (such as night scuba spear fishing), they are more concerned about the effects of pollution and managing pollution as a threat to the reefs. The importance of the pollution attribute is not surprising since pollution has negative effects on both consumptive (e.g. fishing) and non-consumptive benefits (e.g. snorkeling, beach use) of coastal waters. In addition, many residents are likely to have had some exposure to the negative effects of pollution: several recreational and fishing areas around Guam were recently closed due to contamination.

The economic importance of Guam's reefs

The main objective of this study was to determine the economic value of Guam's marine-ecosystems. At the core of this economic value are the various ecosystem functions associated with coral reefs. These, in turn, translate into reef-associated goods and services used by Guam society. These goods and services include reef-based fisheries, the support of tourism in general (and in particular, reef-associated water sports), biodiversity values, amenity values, coastal protection, and cultural values. The sum of these values forms the Total Economic Value (TEV), representing the entire economic importance of Guam's marine environment.

Fisheries: Over the last few decades, Guam's reefs have been impacted by land based pollution, fishing pressure, and loss of habitat. The island's catch per unit effort (CPUE) data suggests that this has led to a decline in local fisheries resources. Despite these negative trends, Guam's reefs provide important fisheries benefits..Compared to other marine habitats, reefs generally create more opportunities for feeding, breeding and refuge from predation for fish and invertebrates. To determine the economic importance of reef-related fisheries, both the market and non-market value of reef fishing was taken into account. The non-market value relates to the cultural importance of fishing in Guam, which was determined at US$3.42million in the choice modeling section of this study. The market value of reef-related fisheries was determined by identifying the market value of the reef fish catch. On the basis of fishery statistics and interviews with fishermen, the annual catch of reef-associated fish (both inshore and offshore) was found to be around 130 tons. Given the relatively high, and increasing real prices of fish in Guam (Figure E.3), the reef-related market value of fisheries amounted to US$ 0.544 million. The total fishery value amounts to US$3.96 million.

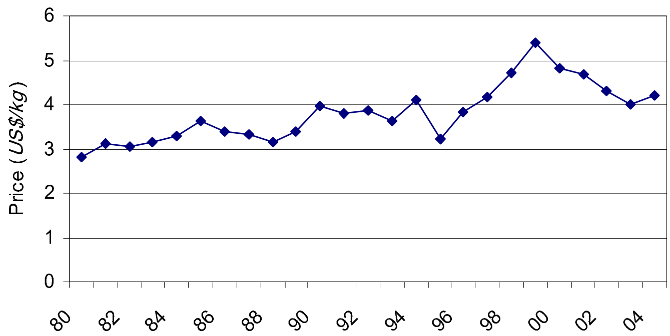


Figure E.3 Price development of commercial fish in Guam (in US$/kg)

Source: PIFSC, 2005.

Tourism in general: Although water sports are of substantial direct value to Guam's economy, the indirect value of reefs to the tourism industry is even more important. Tourists predominantly come to Guam because of the presence of clean beaches and pristine reefs, without necessarily using these amenities. The tourist exit survey shows that, on average, 28.5% of tourist sector revenues depend on healthy marine ecosystems (Table E.3). Once again, calculating the producer surplus (i.e. US$85.4) and the consumer surplus (i.e. US$9.23), we calculated that the reef value per visitor amounts to US$94.63. With one million people visiting Guam every year, this leads to a marine-associated economic value of US$94.6 million per year.

Table E.3 Motivation to visit Guam (% of Survey Respondents)

Nationality	Scuba diving	Water sports*	Sea, Sun, Sand
Japanese	5	16	40
Korean	2	6	18
Hong Kong	15	30	51
Taiwan	13	21	40
US/Hawaii	8	2	11
Weighted average	5.0	14.8	37.1

* Non Tour Package

Source: GVB 2000, Master Report

Water sports: An important direct use value is generated by the reef-related water sports industry. These recreational activities generate direct revenues for local and foreign enterprises operating in Guam. For example, the annual number of dives in Guam is estimated to be around 300,000, of which one third consists of local dives and two thirds international dives. Similar estimates have been made for other marine-related recreational activities, such as snorkeling, surfing, dolphin watching and scuba diving. To determine the value of these marine ecosystem services, we transformed the price of each water sport activity into an economic value. This was done by estimating the producer and consumer surplus of each marine-related activity. The total annual value of marine-related water sport activities amounts to US$8.7million.

Biodiversity: Guam's proximity to the Indo-Pacific center of marine biodiversity has resulted in the presence of numerous species of corals, fish and invertebrates. Recent decline in CPUE prompted Guam to establish five marine preserves, covering approximately 11% of the island's coastline. Substantial research funds around the world have been allocated to study Guam's reefs, in order to gain knowledge about the functioning of marine ecosystems. In the past five years alone, numerous organizations have been involved in the monitoring and research of Guam's reefs. Their overall budget was estimated to be around US$2 million per year. We use this estimate as the proxy of the biodiversity value of reefs in Guam.

Amenity: The view and presence of a clean beach and a healthy coral reef is perceived as a benefit by those living nearby. As such, houses and hotels in the vicinity of a healthy marine system are generally more valuable than comparable properties further from the coast. This amenity-associated value was estimated through a statistical analysis of a database containing information on more than 800 house sales in Guam during 2000-2004. It showed that with every additional kilometer from the coast, the value of a given house declined by US$17,000. By extrapolating this relationship, the annual amenity value of coastal attributes in Guam was estimated at US$9.6 million.

Coastal protection: Reefs function as natural breakwaters; they absorb much of the incoming wave energy and help protect the shoreline from wave attack. In the absence of reefs, rates of coastal erosion and beach loss (and associated economic damage) would be significantly higher. This coastal protection function is especially crucial because Guam is located within the "typhoon belt" and therefore frequently subjected to tropical typhoons. Historic trends show that these storms are becoming more frequent and intensive; at the same time, the potential economic damage has increased due to continuous coastal development. Using GIS, the potential flooding zones caused by storms (and subsequent number of damaged buildings) were determined for two scenarios: 'with reefs' and 'without reefs' (Table E.4). With coral reefs in tact, the average damage each year amounts to US$4.3 million. Without the presence of reefs, this damage would increase to a level of US$12.7 million per year. Therefore, the coastal protection value of coral reefs in Guam is estimated at US$8.4 million per annum.

Table E.4 Number of buildings at risk annually from Western and Eastern storms in a situation with and without coral reefs

Scenario	East (80%)	West (20%)
Potentially destroyed buildings with reefs *(# building)*	667	502
Additional potentially destroyed buildings without reefs *(# building)*	1459	395
Value of at risk buildings with reefs *(million US$)*	90	68
Additional potentially destroyed buildings without reefs *(million US$)*	197	53
Ratio of property value loss of affected building	5%	5%
Value of at risk buildings with reefs *(million US$)*	4.5	3.4
Additional potentially destroyed buildings without reefs *(million US$)*	9.8	2.7

Total economic value: After calculating the economic values of the individual coral reef associated goods and services, we aggregated these values to determine the TEV (Table E.5). The TEV of US$127 million per year represents the economic importance, in absolute terms, of use and non-use values of coral reefs in Guam. The tourist industry in general accounts for 74% of the TEV. Of second and third importance are the amenity (8%) and watersports (7%) segments. Typically, with only half a percent, the only consumptive good (i.e. market value of the fishery sector) is almost negligible compared to the other non-consumptive goods and services. Thereby, coral reefs and its surrounding marine environment represent a significant asset to Guam's economy and culture. Most probably, this importance is not entirely reflected by the funds that are made available by the Guam government to manage the reefs.

Table E.5 Total Economic Value of coral reefs in Guam

Type of reef-related value	Economic value (*million $/year*)	Economic value *(% of total*)
Tourism	94.63	74.30%
Diving and snorkeling	8.69	6.80%
Fishery	3.96	3.10%
Amenity	9.60	7.50%
Coastal protection	8.40	6.60%
Biodiversity	2.00	1.60%
Total Economic Value	127.28	

The spatial variation of reef-associated values and threats

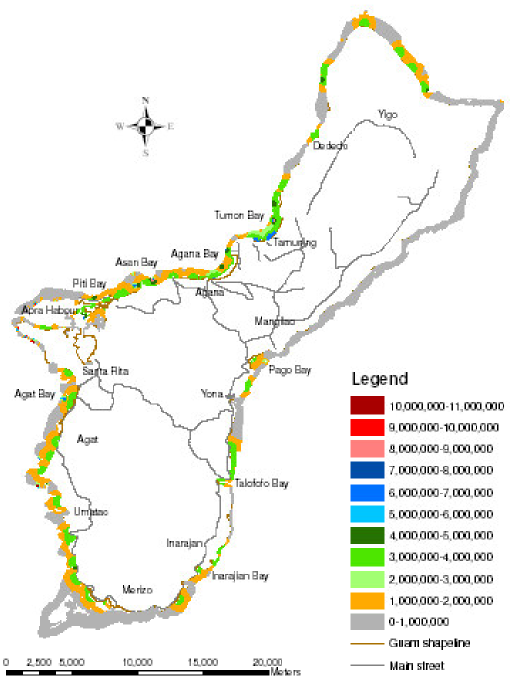
The spatial dimension of interactions between the economy and coral reef ecosystems is relevant at various levels. For example, the magnitude of threats to reefs often depends heavily on their location [e.g. their proximity to i) storm water runoff channels, ii) locations most prone to typhoon damage, or iii) sites with high fishing pressure]. Similarly, beneficiaries of reefs' goods and services are not spread evenly throughout

Guam. They vary according to, for example, the distribution of real estate along the coastline or the spill-over distance of juvenile fish moving between MPAs and fishing grounds. For example, a recent study in American Samoa showed that reef values in some areas were up to 130 times the territory average (Spurgeon and Roxburgh, 2004). Major over- or underestimation can occur if such values are applied (without adjustments) to another area of reef or are extrapolated across whole regions. In this study, we applied GIS techniques to increase our understanding of the spatial variation in economic values of coral reefs in Guam. This allowed us to devise more effective policy recommendations.

Total Economic Value: To determine the variation in economic value between the different reefs, we created a map showing the spatial distribution of the Total Economic Value (TEV). This was built from an aggregation of six maps of individual value categories: fisheries, tourism, recreation, amenity, biodiversity and coastal protection (see Figure E.4a). Although the average value per square kilometer amounted to US$2 million, the highest value was almost US$15 million. This highest value measures only 200 square meters and comprised the most popular diving and snorkeling sites.

Threats: Guam's coral reef ecosystems are under great pressure from various human activities. Specific threats include sedimentation, eutrophication, freshwater runoff from storms, overharvesting and tourist overuse (Figure E.4b). These threats differ widely in nature and magnitude, and also show great spatial variability. Typically, the most threatened reefs are also the most economically valuable. This is dictated by the rule of thumb that humans are the origin for economic importance but at the same time are the main cause of threats to the reefs.

(a) Total Economic Value (TEV) map



(b) Anthropogenic threat map

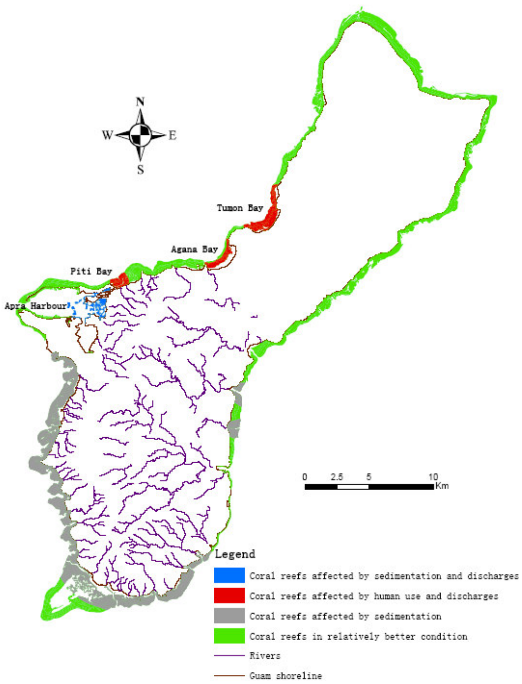


Figure E.4 The Total Economic Value map (a) and the anthropogenic threats map (b) of coral reefs and associated resources in Guam

Integrated approach: The comparison of areas in terms of threats and economic value provides a sound basis for prioritizing coral reef management measures in Guam. From an economic perspective, it is preferable to protect areas of highest value. At the same time, protection should be directed to particularly vulnerable areas facing serious threats. The costs of policy measures need to be taken into account, and minimized wherever possible. Management interventions can be most easily selected using a spatial cost benefit analysis, which allows areas with high economic values, significant threats and low costs of intervention to be identified.

Priority reefs and policy intervention measures in Guam: Having compared the distribution of reefs' total economic value and their anthropogenic threats we conclude that, in general, the more valuable coral reefs are in relatively poor condition and face more serious threats as a result of human impacts. We identified a number of important areas in need of protection:

- The most valuable coral reefs are located within 200 meters of the most popular diving and snorkeling spots. Because diving sites are normally far from the coastline, coral reefs around them are in relatively good condition. However, some of these valuable reefs are affected by discharges and sedimentation from the land. These reefs should be properly preserved to maintain their extremely high economic value.
- Coral reefs in the inner areas of Tumon, Agana and Piti Bays are valuable because of their proximity to the numerous hotels, beaches and parks in these bays. Because of inadequate planning and management and possibly intensive fisheries, coral reefs have inevitably been affected by the pressures of human use and discharges from the land. Effective management measures could include building more wastewater treatment plants to reduce discharges and sewage outflows.
- Coral reefs along the southern coastline of Guam have a relatively high economic value because of their roles in tourism, fisheries, coastal protection and amenities provision. However, due to serious sedimentation, these reefs are highly threatened. Proper land planning and management are needed to diminish this sedimentation and protect these valuable coral reefs.
- The coral reefs located in the north and northeast of the island are in better condition, but their economic value is relatively low.
- Another positive finding is that coral reefs in the very north of Guam can be considered highly valuable as well as being in better condition.

Conclusions and recommendations

To provide economically-sound guidance to decision makers on the management of coral reefs, one could subsequently:

1. Identify both the most valuable, and most seriously threatened, reefs in Guam;
2. Determine the type of threat endangering a specific reef and select a number of potentially worthwhile interventions;
3. Evaluate the economic benefits and financial costs associated with these interventions, and;
4. Find sustainable sources of funding for management interventions.

Clearly, the means available during this study were insufficient to complete all four steps listed above. This study carried out step 1, and partly step 2. At the same time, some knowledge was generated to support step 3 and step 4. In other words, pieces of the puzzle have been developed, but there are still insufficient pieces to complete the analysis. Nevertheless, several specific policy recommendations can already be provided on the basis of the outcomes generated in this study.

Recommendation 1: Make use of the cultural importance residents place on marine ecosystems to improve coral reef management.

The survey and choice experiment revealed a strong link between local residents and their marine ecosystems. Most residents are preoccupied about the state of the marine environment and favor stringent measures geared towards its protection. Water pollution followed by destructive fishing methods are their greatest concerns. These concerns can be used to create increased local support for coral reef management. Residents are also a potential source of funding, since a significant share of respondents indicated they would be willing to pay higher taxes for improved marine management. At the same time, residents' bond with reefs could be further enhanced by encouraging children to learn to swim, as well as by supporting campaigns on the importance of coral reefs for Guam.

Recommendation 2: Actively involve the tourism industry in the development of sustainable coral reef management.

More than any other sector in Guam, the tourism industry is a key player in the management of coral reefs. Not only does this sector benefit the most from the presence of abundant and healthy coral reefs, but it is also one of the major causes of marine degradation. Moreover, because of the large number of tourists, this sector can provide the critical mass needed to generate sustainable funding for coral reef management. With this objective in mind, an environmental tourist tax could be introduced, representative of the environmental damage caused by visitors. Similarly, user fees for divers and snorkelers could be introduced more extensively. Such taxes and fees are unlikely to discourage visitors from coming to Guam, especially if it is clearly communicated that the resulting funds are spent on coral reef management only. The advantage of this approach is that it follows the 'polluter pays' principle.

Recommendation 3: Limit the commercial consumptive use of coral reefs by prioritizing stronger enforcement and protection of marine protected areas in Guam.

From a social planner's perspective, a live fish has a higher economic value than one caught and sold at the market. The revenues generated by the commercial fishing industry are small compared to the coral reef associated value for the tourism industry. Viewing fish while diving and snorkeling is more sustainable and more valuable than catching them for commercial purposes. On the other hand, catching fish for private consumption and sharing it with family and friends generates a much higher (cultural) value than that gained at the market. Therefore, recreational fishing outside marine protected areas should not be discouraged: it strengthens the cultural links between local residents and the ocean.

Recommendation 4: Prioritize potential policy interventions in an economically sound manner.

Guam has limited funds with which to manage its valuable marine resources. Therefore, it is important to utilize these funds as efficiently as possible. As outlined, such a selection procedure requires an economically sound decision support tool. The most plausible tool available is an extended cost benefit analysis, which makes explicit the economic benefits gained for every dollar invested in a specific management option. During the interview process, experts in Guam mentioned a number of management options. The top three options were: i) improving the sewage discharge system, ii) reducing sediment runoff from Guam's watershed areas, and iii) increasing environmental education through curricula developed specifically to include the value of coral reefs. These three elements are also explicitly mentioned in Guam's Coral Reef Local Action Strategy (LAS). In future work, economic analysis could be effectively used to evaluate the feasibility of these potential measures.

1. Introduction

The coral reef ecosystems of Guam are unique. Despite its limited size, the island possesses fringing reefs, patch reefs, submerged reefs, offshore banks, and a barrier reef surrounding its southern shores (Figure 1.1). The reef margin varies in width, from tens of meters along some of the windward areas to well over hundreds of meters (Hunter, 1995). More than 1,000 fish species inhabit Guam's coral reefs (Myers and Dondaldson, 2003). These fish play key roles in the ecology of the reefs and have been an important food source since people first settled on Guam (Amesbury and Hunter-Anderson, 2003).

In May 1997, the Guam Government adopted a resolution declaring the importance of maintaining the health and stability of coral reef ecosystems (Underwood, 1997). As such, it was formally recognized that coral reefs are deeply woven into almost every aspect of the lives of Guam's citizens. Healthy coral reefs are vital to Guam's economy, which is largely driven by the tourism industry. At the same time, coral reefs are also an important element in the island's culture. Moreover, the reefs provide natural coastline protection against high waves, storm surges and coastal erosion, especially during typhoons and tsunamis.

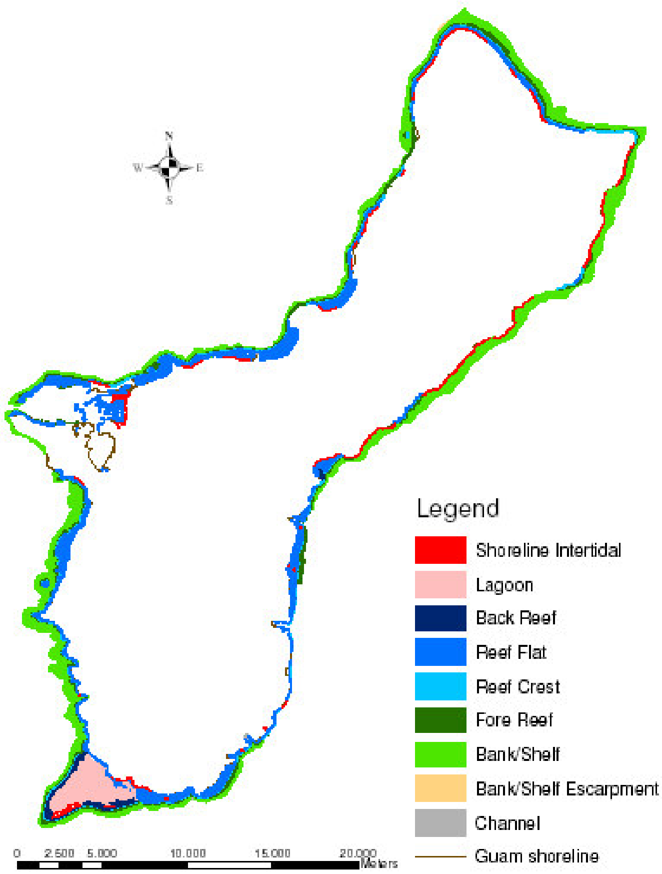


Figure 1.1 The coral reefs of Guam

source: NOAA habitat maps NCCOS, 2005

Despite this formal recognition of reefs' importance to Guam's economy, many human activities are still causing the degradation of reefs and the wider marine environment. Guam's reefs are especially threatened by sewage outfalls, runoff, sediment, silt, and environmental stresses caused by an increasing number of visitors. The rapid economic development driving these threats will ultimately lead to a significant decline in Guam's reef. In turn this could negatively affect many crucial economic sectors in Guam. Due to the lack of knowledge on the economic importance of Guam's coral reefs, the magnitude of such potential damage remains unclear.

Why is it important to determine the economic importance of the coral reefs of Guam? First, economic valuation provides a solid basis to policy makers in Guam to decide at what level the reefs should be protected (i.e. is it worth managing the coral reef? In other words, do the benefits of coral reef management exceed the costs?). Second, it supports damage assessments in case of calamities (i.e. 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?). Third, economic valuation support decisions with regard to rehabilitation of the reef (i.e. do the avoidable foregone benefits exceed the costs of rehabilitation).

Measuring the extent of coral reefs' economic importance in Guam is not a straightforward exercise. Earlier attempts concluded that the ecological services, tourist-related industries and coastal protection function of Guam's reefs were worth US$85 million per year (Richmond, 2000). This estimate, however, was mainly based on secondary data sources and is therefore not necessarily accurate. Moreover, it excludes the cultural importance of reefs, which can also be expressed in monetary terms.

The objective of this study was to carry out a comprehensive economic valuation of the coral reefs and associated resources in Guam. The focus was on valuing the five main uses of coral reefs in Guam. Some of these are extractive uses, such as fisheries (i); others are non-extractive, such as recreation/tourism (ii), cultural/traditional uses (iii), and education and research (iv). Finally, some are indirect uses, such as shoreline/infrastructure protection (v). With a better understanding of the economic importance of coral reefs, Guam's decision makers can formulate more effective policies utilizing limited funds.

Figure 1.2 shows the methodological approach followed in this study to estimate the economic values of the individual benefit categories, and subsequently the Total Economic Value (TEV) of coral reefs in Guam. The estimation of the value of each benefit required specific data inputs. Although a number of secondary data sources were used for this purpose, the most important source of data was the household survey. This provided high quality primary data for the economic analysis. The data collection and valuation procedures are explained in detail in the coming Chapters.

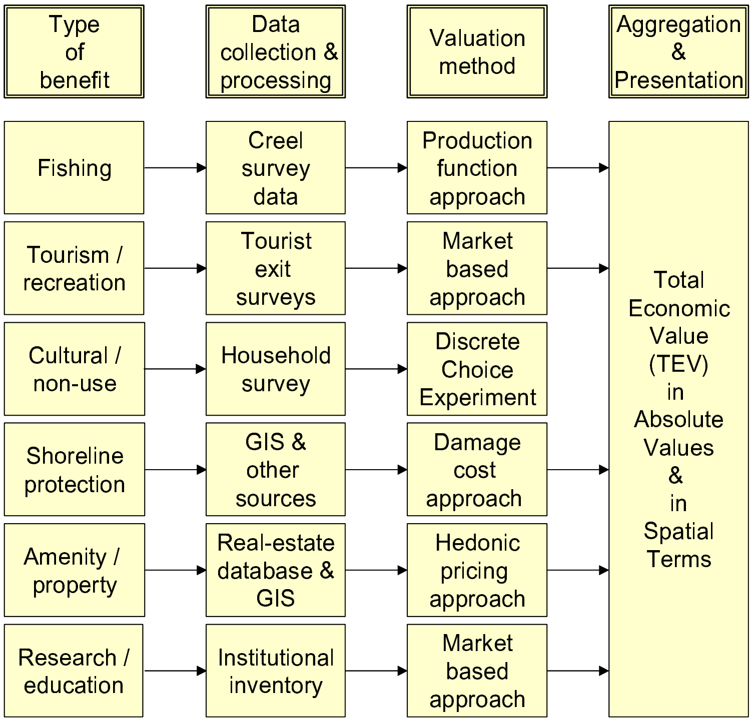


Figure 1.2 Methodological approach of the project

The report is structured as follows: The analysis starts in Chapter 2 with a detailed explanation of the household survey. Certain issues are elaborated upon, such as the residents' habits with regard to recreation and fishing. Chapter 3 presents the outcome of the discrete choice experiment, in which the non-use values of coral reefs in Guam were estimated. The Total Economic Value (TEV) is identified in Chapter 4. This is the cumulative value of several distinct sub-categories, including: fisheries, tourism, water sports, biodiversity, amenity, and coastal protection. In Chapter 5, these separate values are converted into maps in order to demonstrate the spatial variation of the TEV. Finally, conclusions and discussions are presented in Chapter 6. The report contains a number of Appendices in which background materials (such as the household survey and the choice experiment) are shown.

2. Survey results

2.1 Introduction

Coral reefs and other marine related resources play an important role in the lives of Guam's citizens. The strong fishing tradition and the habit of barbequing on the beach provide the basis for a clear bond between the ocean and the people of Guam. Because this relationship has been predominantly built upon tradition, folklore and leisure rather than on financial or subsistence motives, this link is labeled as a 'cultural value'.

To determine the nature and the level of the cultural value of coral reefs in Guam, a survey based on 'choice modeling' was conducted. The survey solicited information about the cultural and ethnic background, age, gender, education and income of the interviewee. This allowed for an analysis of differences in values across different ethnic groups and socio-economic backgrounds. The demographics of the respondent together with other questions gave an insight into how these values are shaped, and how and why perceptions change over time. This survey-based approach was supplemented with key informant interviews and focus group discussions to get a better understanding of the cultural/traditional/non-use values and of trends over time.

From January to March 2005, 400 inhabitants of Guam were interviewed about their relationship with and perception of the island's marine environment. The composition of the sample included the main ethnic and socio-economic groups in Guam. The ethnic selection was based upon the residential areas of different groups. Within the neighborhoods, streets were randomly selected for surveying. Within each selected street, every third house was approached. If the selected household did not want to be involved, the house right next door was approached. The average length of an interview was around 50 minutes.

The questionnaire had several different sections (see Appendix I and II). Part 1 of the questionnaire addressed general issues, including recreation, environmental awareness and the importance of fish in interviewees' diets. Part 2 of the survey was specifically focused on fishing and was therefore only completed by fishermen. Part 3 involved the choice experiment and required specific guidance by the interviewer. Finally, Part 4 consisted of closing questions regarding marine resource management as well as the demographics of the respondent.

The main results of the survey are summarized in the following sections.

2.2 Profile respondents

More than 30% of the respondents are originally from Guam. The remaining 70% immigrated to Guam from various countries. The majority of the immigrants came to Guam in the eighties (28%) and the nineties (38%). When asked about expectations regarding their future in Guam, fewer than half of the respondents were certain about the fact that they would live on Guam for the rest of their lives or at least for another 25 years. Around 20% of the respondents expected to leave Guam in the coming 5 years, of which one third was sure to leave within one year. Very few people emigrated before 1970.

The left-hand side of Table 2.1 reports on the country of origin of the respondents. The right-hand side of Table 2.1 shows the ethnic background of the respondents. Chamorro and Filipino jointly represent half of the survey sample. The third and fourth most important ethnic groups are Caucasian (23%) and Chuukese (12%). This matches well with the actual ethnic composition of Guam's population.

Table 2.1 Country of origin

Country of origin			Ethnic background		
Rank	*Country of origin*	*Number respondents (Share in total)*	*Rank*	*Ethnic background*	*Number respondents (Share in total)*
1	Guam	122 (30.5%)	1	Chamorro	100 (25.0%)
2	Philippines	96 (24.0%)	2	Filipino	100 (25.0%)
3	Mainland US	90 (22.5%)	3	Caucasian	92 (23.0%)
4	Chuuk	44 (11.0%)	4	Chuukese	47 (11.8%)
5	Palau	12 (3.1%)	5	Palauan	27 (6.8%)
6	Yap	10 (2.5%)	6	Yapese	11 (2.8%)
7	Pohnpei	7 (1.8%)	7	Pohnpeian	6 (1.5%)
8	Japan	4 (1.0%)	8	Kosraen	3 (0.8%)
9	Hawaii	4 (1.0%)	9	Japanese	3 (0.8%)
10	The CNMI	3 (0.8%)	10	Carolinian	2 (0.5%)
11	Kosrae	2 (0.5%)	11	Korean	1 (0.3%)
12	Korea	1 (0.3%)	12	Hawaiian	1 (0.3%)
13	Elsewhere	5 (1.2%)	13	Other	7 (1.8%)

Official statistics reveal the following structure of Guam's economy: industry 10%, trade 24%, other services 40%, federal and territorial government 26%. The unemployment rate is around 15% (CIA, 2005). Table 2.2 shows the professional background of the respondents. In line with the economic structure of Guam, the service industry (e.g. tourism, management) is strongly represented (39%). Government employees make up 11% (Guam) and 4% (US) of the sample. The inactive share of the sample is comprised of retired (10%) and unemployed (7%) respondents.

Table 2.2 Professional background of the respondents

Rank	Profession	Share in total
1	Service & tourism	20%
2	Management, professional etc.	19%
3	Guam Government	11%
4	I am retired	10%
5	Sales and office	8%
6	Construction, transport & maintenance	8%
7	I am unemployed	7%
8	Student	6%
9	US Government (non military)	4%
10	Military	3%
11	Farming, fishing, forestry	1%
12	Other, specify	5%

Table 2.3 shows the level of education of the respondents. The majority of the respondents completed high school (32%) and college (20%).

Table 2.3 Level of education

Level	Level of education	Share in total
1	Elementary school	10%
2	High school	32%
3	Some college or university	27%
4	Finished college (bachelor's degree)	20%
5	Advanced degree	10%
6	Don't know/refused	1%

When asked about their annual gross household income, 16% of the respondents preferred not to reveal this information to the interviewer. This is a common response to income-related questions. The distribution of the remaining 84% of the sample is shown in Table 2.4. The average household income of the respondents is US$36,621

Table 2.4 Gross household income (US$/year)

Level	Income group	Share in total
1	$5,000 or less	10%
2	$5,000 to $10,000	15%
3	$10,000 to $20,000	16%
4	$20,000 to $35,000	17%
5	$35,000 to $50,000	16%
6	$50,000 to $75,000	12%
7	Over $75,000	14%

2.3 Recreation

As well as being a classic example of a tropical paradise for many tourists, Guam also provides many recreational services to residents. Table 2.5 shows how often anyone in the household participated in a number of recreational activities. Most households have barbeques on the beach (92%). The average household will have a barbeque at least once a month (13.2 times a year). Bathing or swimming in the sea is also a common activity (87%). This is somewhat surprising because, when asked about their swimming skills, only between 11% and 16% of the adult members of the household indicated they were able to swim. For the children in their households, this percentage is even lower (9%). Nevertheless, the high participation rate for swimming proves that despite their limited skills, resident do not avoid the water. Other popular recreational activities that are more directly related to the marine environment include fishing (45% of households), snorkeling (44%), kayaking (21%) and scuba diving (19%).

Table 2.5 Recreational activities in Guam

Rank	Activity	Days per household/year	Share of active respondents
1	Swimming/wading	17.01	87%
2	Beach picnic/barbeque	13.26	92%
3	Fishing	9.05	45%
4	Snorkeling	7.40	44%
5	Kayaking/paddling	2.73	21%
6	Scuba diving	2.65	19%
7	Body boarding/ surfing	1.75	12%
8	Jet skiing	1.73	14%
9	Windsurfing/ kiteboarding	0.25	5%

The households were also asked to indicate the 1st, 2nd, 3rd and 4th most important condition for recreation. By attaching weights to these various conditions (i.e. 0.5 for the 1st, 0.3 for the 2nd, 0.15 for the 3rd and 0.05 for the 4th), the four selected conditions were aggregated into one score. Table 2.6 shows this ranking. Clean and clear waters are considered to be the most important factor contributing to high-quality recreation (25%). Good public facilities such as restrooms and barbeques come second place (22%). For the sake of the safety of their children, respondents also consider safe and calm waters as relatively important (17%). Fishing is often viewed as a cultural, commercial, or subsistence activity, rather than recreational, so it is not surprising that abundant fish stocks score low as a desired conditions for recreation..

Table 2.6 Desired conditions and facilities for recreation on Guam

Rank	Conditions and facilities	Importance
1	Clean and clear waters (unpolluted, good visibility)	25%
2	Good public facilities (e.g. barbeque, restroom)	22%
3	Safe and calm waters	17%
4	Clean and wide beach	15%
5	Healthy coral reefs	6%
6	Abundant fish stocks	4%
7	Plenty of parking space	3%
8	Proximity to home	3%
9	Other, specify …	4%

2.4 The dietary importance of fish

Fish have considerable cultural significance in Guam. Traditionally, fish were one of the primary sources of animal protein for local inhabitants of the island. In the early days, families in coastal villages would use fish to barter for produce raised by families living in more interior locations of the island. The westernization of the island over the past decades has reduced this dependence on fish, but fresh-caught fish is still a common, prized addition to the fiesta table. In addition to fish, the reef also provides octopus, shellfish, and certain species of marine algae for consumption.

Although households traditionally caught fish for their own consumption, this has changed significantly over time. Table 2.7 shows the main sources of fish/seafood consumed by the respondents' household; more than half of the consumed fish actually comes from stores or restaurants, where the majority of the fish on sale is from overseas. The second most important source of fish is the immediate household (24%) or the extended family or friends (14%). Buying fish at the road side (3%) or at flea markets (6%) is not very common.

Table 2.7 Main sources of consumed fish/seafood

Rank	Source	Share of people	Share of consumption
1	Purchased at a store/restaurant	39.9%	51%
2	Fish caught by myself or by immediate family	20.4%	24%
3	Fish caught by extended family or friend	20.3%	14%
4	Purchased at flea market	10.9%	6%
5	Purchased from the road side	5.6%	3%
6	Other	2.9%	3%

When asked about the origin of the consumed fish, respondents generally gave accurate answers. Table 2.8 shows their perception of where the fish was caught. The four main sources of fish are quite evenly represented. Despite the increasing importance of fish imported from other Pacific islands (23%) and the US mainland (20%), the main source of fish still seems to be Guam's waters. 32% of the fish is identified as reef fish, and 25% as coming from outside Guam's reefs.

Table 2.8 Main sources of the consumed fish/seafood

Rank	Source	Share of people	Share of consumption
1	Fish and other species from inside Guam's reefs	31%	32%
2	Fish caught outside Guam's reefs	27%	25%
3	Imported fish/seafood from other Pacific islands	22%	23%
4	Imported fish/seafood from the mainland	21%	20%

2.5 Environment

The respondents had strong opinions about the change in Guam's marine environment. When asked about perceived long-term changes, most of the respondents confirmed a decline in quality of the main components of the marine environment. On average, 55% of the respondents felt that the marine environment had worsened in the last decades. Only 7% of the respondents witnessed improvements while, on average, 11% of the respondents did not observe any change. 25% of the respondents did not answer this question due to a lack of knowledge.

Water quality (79% witnessed negative changes) and fish abundance (61% witnessed negative changes) are seen as the most threatened aspects. These are also the environmental elements that the local population values most. For swimming and bathing, water quality is obviously an important factor. Similarly, a decline in fish stocks affects the quality of fishing trips conducted by most families in Guam. Also, awareness about water quality and fish abundance is enhanced due to media attention of pollution spills (e.g. broken sewage pipes) and depleted fish stocks. Although one may expect a lack of swimming skills to limit concerns with regard to coral reefs, live coral abundance is also seen as a highly threatened marine component (53% witnessed negative changes).

Apparently the respondents are informed about the state of reefs through family and friends, or through radio and television.

To test respondents' further knowledge of the environment, a question was added on the 1st, 2nd, 3rd and 4th most important causes of the change in quality of the marine environment in Guam. By following a similar aggregation procedure as that used in Figure 2.1, the scores for each possible cause were aggregated and ranked accordingly (see Table 2.9). Three perceived causes clearly dominate: increased runoff and storm water (20.7%), sedimentation due to poor development practices (20.6%) and leakage from broken sewage pipes (18.4%). Typically, the direct damage caused by tourism is not considered to significantly contribute to the degradation of the marine environment. Jet skiing, banana boats, diving and snorkeling operations jointly scored less than 7% of the total causes.

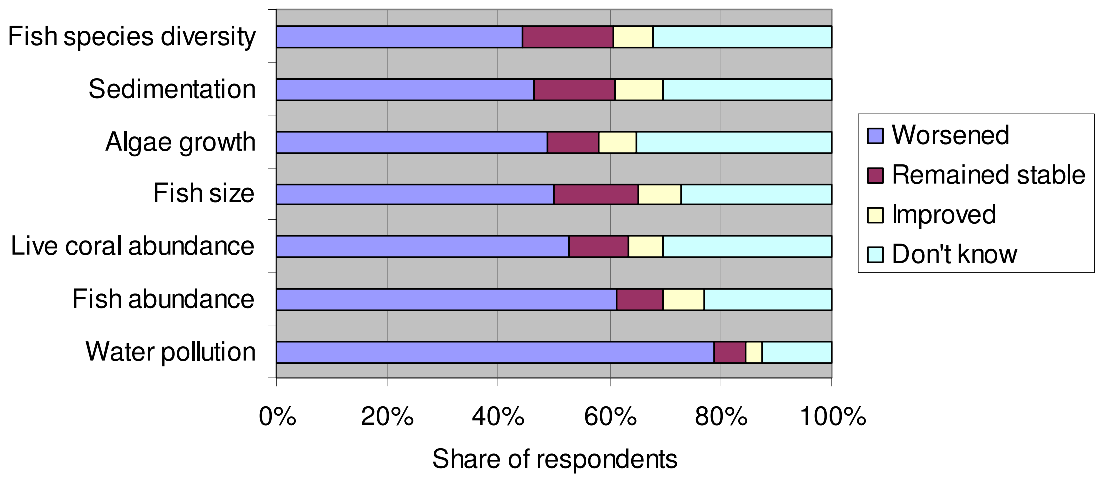


Figure 2.1 Perception of changes in Guam's marine environment

Table 2.9 Perception of causes of changes in Guam's marine environment

Rank	Perceived cause of environmental degradation	Importance
1	Increased runoff and storm water	20.7%
2	Sedimentation due to poor development practices	20.6%
3	Leakage from broken sewage pipes	18.4%
4	Use of improper fishing techniques (gillnets, night scuba)	9.5%
5	Increased pesticide/fertilizer runoff from golf courses and hotels	7.6%
6	Sedimentation due to intentionally set fires	6.3%
7	Too many fishermen	5.7%
8	Too many jet skis, banana boats	5.1%
9	Too many divers and snorkelers	1.9%
10	Other, specify …	4.2%

Next, the respondent was asked the following question: "Imagine that you are the governor of Guam and that you are in a position to do something about the management of the reef fish and corals in Guam. Please indicate the 1st, 2nd, 3rd and 4th most important measure that you would take to improve the marine environment in Guam." The outcome is shown in Table 2.10. Again a clear top-3 emerges from the list. Improvement of the sewage system is considered to be the most urgent measure to be taken (19%). Education is also seen as a vital component of sound management of the marine environment (17.3%). Law enforcement is also seen as crucial, in terms of stricter rules for development (17.2%), enforcement of existing laws (10.1%), and increased penalties for violators (8.7%).

Table 2.10 Perception of required management to improve Guam's marine environment

Rank	Perceived required environmental measures	Importance
1	Improve the sewage system (e.g. repair/extend sewage pipe)	19.0%
2	Educate children and general public about marine ecosystems	17.3%
3	Set and enforce stricter rules for development	17.2%
4	Improve enforcement of existing laws	10.1%
5	Increase the penalties for violators of existing laws	8.7%
6	Outlaw the intentional setting of fires that cause sedimentation	7.3%
7	Prohibit jet-skis in areas where they can damage the reefs	6.0%
8	Reduce pesticide/fertilizer use at golf courses and hotels	4.0%
9	Prohibit the use of gillnets	2.2%
10	Open marine protected areas during certain periods of the year	2.0%
11	Limit recreation to popular marine sites (i.e. divers, snorkelers)	1.9%
12	Prohibit spear fishing at night	1.4%
13	Other, specify …	2.9%

2.6 Fishing

Traditionally, fishing in Guam is an important means of establishing and maintaining cultural and familial ties. It is not uncommon to see local families spending time fishing together on the weekends. The modernization of Guam is a threat to the local culture and language. In particular, the teaching of local fishing practices to younger generations by elders is a crucial part of maintaining the indigenous culture.

To learn more about the cultural importance of fishing in Guam, a separate fishery component was added to the household survey. This component was completed by 130 respondents. It suggests that 35% of the overall sample of 400 respondents is involved in fisheries. This is not entirely in line with the 45% expressed in Table 2.5. The difference can be partly explained by the fact that respondents who complete the fishery survey are active fishermen. In contrast, respondents in Table 2.5 include those who join family members or friends on fishing trips, but do not consider themselves to be real fishermen. Another explanation may be that some fishermen refused to fill in the fishery component due to fatigue from the general survey and the choice experiment. In conclusion, the actual share of households in Guam involved in fishing is probably somewhere between 35% and 45%.

Most of the respondents were skilled fishermen, with more than 10 years experience (66%). On average, fishermen go fishing 48 days a year (i.e. almost every week) for a duration of 5 hours. However, as shown in Figure 2.2, the frequency and duration of these trips varies a lot. Some fishermen fish every day (2%), while others fish only once a year (2%). 29% of the fishermen are boat owners.

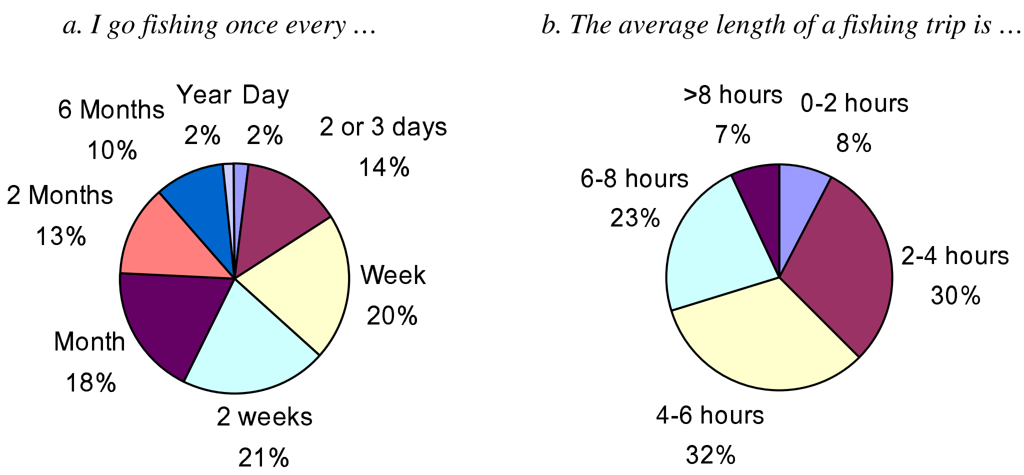


Figure 2.2 Fishing frequency and trip duration

One of the objectives of this study is to find out whether and why fishing behavior has changed compared to 10 years ago. Of the 131 respondents, 85 fishermen claimed to have changed their fishing frequency. As shown in Figure 2.3, fishermen on average go fishing more frequently now than 10 years ago. The average number of fishing days for those 85 fishermen that have changed their behavior has increased from 85 to 95 days per year. The reasons for this change are shown in Table 2.11. Generally, the change is due to respondents having more time available (37% out of 50%). This, in turn, can be explained by the fact that this group is now older and in some cases retired (20%). Also important is the fact that fishermen felt fish abundance had changed in Guam's waters. The catch per unit effort has declined in the last 10 years. Therefore the fishermen have to spend more time at sea in order to catch the same amount of fish.

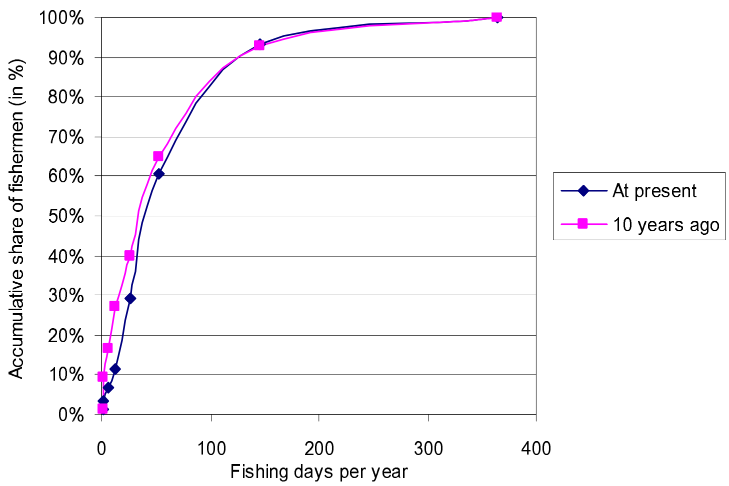


Figure 2.3 Fishing distribution at present and 10 years ago

Table 2.11 Reasons for changing fishing habits

Rank	Reason for change	Importance
1	Because I have less/more time than before to go fishing	37%
2	Because I have grown older	20%
3	Because fish availability has changed (quantity and size)	16%
4	Because my family's need for fish has changed	7%
5	Because the cost of fishing has changed (fuel, gear, etc.)	6%
6	Because my need for additional income from fishing has changed	3%
7	Because my family has changed their diet (less or more fish)	2%
8	Because I only started fishing recently	1%
9	Other, specify …	8%
10	Don't know	1%

A wide range of fishing techniques is used in Guam. The most popular techniques include hook and line fishing at depths of less than 100ft (18.6%), trolling (16.5%), and spear fishing (with a snorkel) at night (14.9%) and during the daytime (14.8%). Almost half of the fishermen use one or more of these three techniques. Despite gillnetting and spear fishing with scuba gear ('scuba spear fishing') being destructive fishing techniques, they are still practiced by 17% and 8% of fishermen, respectively.

When asked how often the respondent encounters people using illegal fishing techniques (such as dynamite fishing, chlorine fishing, and fishing in marine reserves) or how often they find evidence that people have recently used illegal techniques in an area, the majority claimed to have never witnessed illegal fishing practices. 15% of the respondents witnessed illegal practices rarely, while 18% see them occasionally. Regular witnesses account for 6% of the interviewed fishermen.

Table 2.12 Distribution of fishing techniques

Rank	Fishing type	Importance	Participation rate
1	Bottom: hook & line (less than 100ft)	18.6%	45%
2	Trolling	16.5%	44%
3	Snorkel spear fishing at night	14.9%	45%
4	Snorkel spear fishing during daytime	14.8%	42%
5	Cast net (Talaya)	8.6%	28%
6	Bottom: hook & line (more than 100ft)	6.0%	20%
7	Gill net (Tekken)	4.5%	17%
8	Drag and surround net (Chenchulu)	3.5%	12%
9	Trapping (octopus, crabs, etc.)	2.5%	20%
10	Scuba spear fishing at night	2.5%	11%
11	Scuba spear fishing during the day	1.9%	8%
12	Foraging the reef (shell, crabs, etc)	1.4%	8%
13	Other techniques	4.3%	13%

Table 2.13 shows the main reasons why the fishermen go fishing. By far the most important motive is pleasure (39.1%). The subsistence motive, "I really need the fish to feed my family", comes in second place with 15.4%. The two motives that are culturally driven, "Giving my catch to family and friends strengthens social bonds" and "Tradition: My family has always fished. Fishing is my life!" come third and fourth place (with

14.5% and 11.5%) respectively. Fishing is rarely done for purely financial reasons, proven by the low score of the motive "I really need the money from the fish I sell" (2%).

Table 2.13 Motives to go fishing

Rank	Motives for fishing	Importance
1	I really enjoy fishing	39.1%
2	I really need the fish to feed my family	15.4%
3	Giving my catch to family & friends strengthens social bonds	14.5%
4	Tradition: My family has always fished. Fishing is my life!	11.5%
5	Fishing strengthens the bond with my children/family	5.0%
6	Fishing strengthens the bond with my fellow fishermen	4.0%
7	I really need the money from the fish I sell	2.2%
8	I go fishing to catch fish for fiestas/parties	2.0%
9	I do seasonal fishing for manahak, ti'ao, and e'e	0.8%
10	Other, specify …	5.5%

Table 2.14 shows the composition of the monthly fishing costs of the respondents. Using different methods for calculating the average costs, the maximum and minimum monthly costs are US$186 and $104, respectively. This implies average costs of US$145 per month. The main cost items include fishing equipment and fuel. Scuba tanks are considered a cost item by 9% of the respondents, despite the destructive nature of scuba spear fishing. Note that outliers have been excluded from this cost calculation, so as to exclude the semi-commercial fishermen.

Table 2.14 Average monthly fishing expenses (US$ per month)

Cost item	Maximum	Minimum	Average	Share of response
Fuel & oil	56	35	45	66%
Ice	14	10	12	68%
Fresh bait	20	9	15	46%
Fishing equipment	57	43	50	78%
Scuba tank fills	37	3	20	9%
Other	39	8	23	20%
Total costs*	186	104	145	

Note: Because a minority of the fishermen practice scuba spear fishing, the costs of scuba tank fills is excluded from the average total costs.

Out of the 130 'fishing' respondents, only 30 fishermen sell part of their catch (see Figure 2.4). The selling of fish catch is mainly practiced to recover part of the costs of fishing. On average these "selling" fishermen earn US$252 per month from these sales.

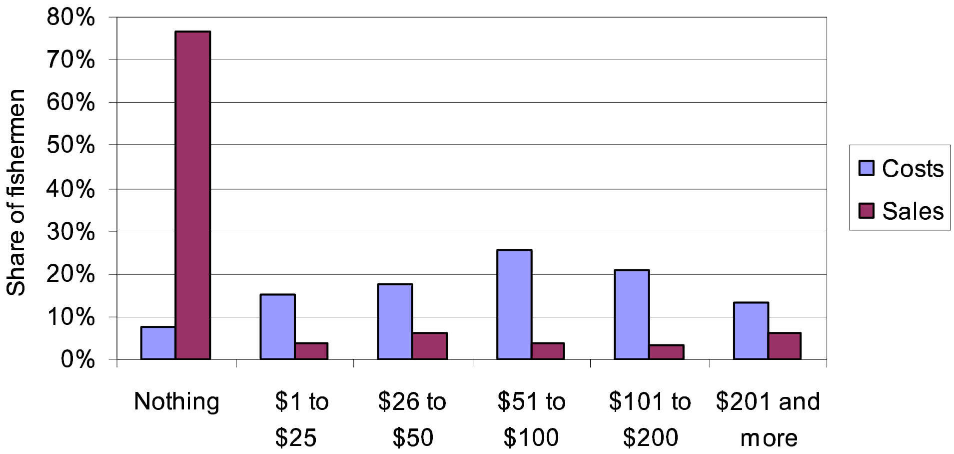


Figure 2.4 Distribution of total fishing-related costs and benefits

If we look at the motives for fishing for the "selling" fishermen, and compare these to the motives of the overall group of fishermen, some interesting conclusions can be drawn. The most important reason for fishing for the semi-commercial fishermen is: "I really need the fish to feed my family" (31%). For the overall group, this argument scores only 15%. Also, when we look at the average income of this semi-commercial group, it appears that, at US$42,854, it is higher than the average income of the overall group of fishermen (at US$36,621). Compared to the average fisherman, the semi-commercial fishermen are substantially more actively involved in trolling, deep-sea fishing with hook and line, gill netting, and scuba spear fishing. Moreover, of the fishermen who sell their catch, 60% are boat owners; of those that do not sell fish, only 29% own a boat. In other words, it seems unlikely that fishing is truly necessary to earn cash income for the family.

Box 2.1 The catcherman

Simon R. Camacho, Jr. quickly sets himself apart from others. "I'm not a fisherman, I'm a catcherman. There's a difference. I catch fish. I have different views from fishermen you come across," Camacho said. He doesn't tell tales of the big one that got away. Instead, his stories are about personal responsibility, an ethic he lives by and promotes to others, especially the youth. "When I come back from the reef, I have a basket of fish and a bag of garbage."

Camacho casts a staunch conservation creed that he hopes will catch on. "I encourage the kids to think: 'This is my island,' and to pick up trash when they're out fishing," Camacho said. "I ask my nephews, 'Would it kill you to pick up all the trash and have one of you bring it back?' Simple things like cigarette butts people flick it in the water, and this is the water we get our food from. Some people don't get it. I tell people, 'If you have to smoke, put it in your pocket'".

The Mangilao resident's favorite fishing grounds have been trashed. "My biggest problem," Camacho said, "is people's bad habits." He said he might have up to four large sacks from one area alone of discarded refuse. "You'll see pampers, beer bottles, soda cans, leftover foods, and paper (along East Agana Bay). It's irritating. Somebody's gotta pick it up, sometimes that person happens to be me." He said pollution, greed, technology, and the lack of education are to blame for Guam's marine problems.

The ninth of 11 children, Camacho, 46, learned how to fish from his father at an early age. But it was his godfather and master talayeru, Jose A. Punzalan, whom he credits for his skills in catching fish and weaving talayas (traditional fish nets). Camacho apprenticed under Punzalan at age 12. "My nino did every kind of fishing," Camacho said. "Before you'd have to apprentice under someone for years and just carry his net." The apprenticeship also taught him about a code of conduct. "If you're in the water, I don't walk toward you or I wait." Over the years, he said he's seen that code violated and greed take over,

"Some people are seasonal fishermen," Camacho said. "They are only out there when they can turn quick cash. The problem is certain people don't know how to control, how to self-regulate what they're doing. I can fish till there's nothing, but what does it do for me?" He said he's seen fishermen waste truckloads of fish. They'd circle about 20 truckloads of atulai (big eye scad) in the water and at the end of the day remove one or two truckloads. Out of the 20 schools, he said, they'd only manage to sell half, the other half rotted in the water or was dumped. "It has a lot to do with greed. If no one wants (to buy the fish) in 24 hours, set them free," he said. Camacho doesn't waste fish or catch what people don't want.

Camacho, an assistant manager for transmission and distribution at the Guam Power Authority, has held a full-time job the last 27 years. "But fishing," he said, "was what kept my family from not starving." "I don't catch things that people don't care for." He added, "I don't catch what I don't eat." He said his wife likes rabbitfish a certain size. "Any bigger, she doesn't want; any smaller she don't want it. What I remember with the older folks is they were picky, too."

"I've seen the good old days and technology is part to blame for our problems," Camacho said. He attributes the declining fish population to technology and population growth. Technology has made it easier to fish, he said. "Before it was hard to get materials, now you can buy nets a dime a dozen." "The value of a net was more," Camacho said. "Back then, you don't ask to borrow a net, it was unheard of." He said these days people have no problems asking. "It's the Chamorro way, and I have to go borrow it back," he said.

The ready supply of nets combined with the range of diameter sizes has Camacho concerned about sustainable fish yield. "You'd be surprised what three-eighths of an inch would make," he said. Camacho is in favor of regulations that are fair and regulating the size of gill nets to no smaller than two inches. He said the law would be more effective if the supply was regulated. "If it's going to be made illegal, it needs to be made illegal at the stores," he said.

Fishing on Guam has changed for Camacho. The marine preserves and security restrictions at Cabras Island after September 11 have made fishing challenging. "I've been around long enough. I've seen the good old days," he said. He recalled the days when fish yield was abundant. "In my 20s, I remember just throwing once … and going home. Now, I'm (in the water) up to two or three hours," Camacho said. "I remember before, every year it was like clock work (the manahak) would come in every April," he recalled.

Camcho also doesn't care much for the machinery on Tumon's sands or jet skis he's witnessed fuel up in the water. "The reef racker," is damaging the coastline, he said. "It irritates me to see the guy take the rake into the water. What is the tractor doing in the water — if he has an oil leak, the oil goes in the water," Camacho said. He said he welcomes the tourists, but thinks the hotels and GVB can do more for the environment. Instead of anchor blocks that are moored in the water to keep kayaks in place, he'd like to see them brought out to the water when the tourists are ready.

Camacho is also concerned about the island's pervasive litter problems. "They cry about tourism. If you're a tourist, would you want to come to an island that's filthy? I wouldn't. We could do a lot better. We could start enforcing the litter laws," he said.

"What I take upon myself is responsibility." Camacho, a father of six children, said he's taught his 21-year-old daughter the skills of sewing a fish net. The skills and ethics he's passing on are Camacho's hope for a better island. "I remember even when the smell of the ocean is different. Nature can take care of its own. It doesn't need man's meddling."

Written by Grace Omega Garces

3. Choice modeling

3.1 Introduction

The household survey described in Chapter 2 also included a discrete choice exercise. This was designed to estimate the value of some non-market benefits associated with Guam's coral reefs, such as cultural/traditional, recreational, and non-use values. Because choice modeling applies a different technique to the common survey approach, we discuss the outcome of this exercise separately. This begins in Section 3.2 with an introduction to discrete choice modeling methods in the context of economic valuation. Section 3.3 follows with a general overview of the theory and methods associated with choice modeling; it concludes with an overview of the development and implementation of the stated choice experiment used to define the non-market benefits associated with Guam's coral reefs. Section 3.4 provides the results of this experiment. Finally, the chapter closes with a discussion and final conclusions (Section 3.5).

3.2 Methods

Valuing non-market goods

Coral reefs are of considerable value to Guam's residents. This value cannot be measured by market activities alone. As a small island in the middle of the Western Pacific, Guam's economy was traditionally dependent on resources provided by the reefs. As a result, the original Chamorro population developed a rich fishing culture. This economic dependence on reefs has declined due to Guam's integration into the world economy. Nevertheless, descendents of Guam's original Chamorro people (as well as its many immigrants) place a high value on maintaining the social and cultural values associated with reefs. For example, the migratory return of traditional fish such as ti'ao (baby goat fish) and manahak (baby rabbit fish) is of special significance, and friends and families are brought together to share in this harvest. In addition to more traditional cultural values, the reefs and associated beaches provide residents with places for Fiestas and barbeques, sheltered locations for swimming, and opportunities to enjoy nature.

The importance of traditional, cultural, recreational, and non-use coral reef values is not completely reflected by market activity. As such, traditional market-based economic techniques that rely on observing the behavior of real markets cannot be depended upon entirely to estimate non-market values. Instead, stated preference methods can be used. The most well-known stated preference valuation method is the contingent valuation method (CVM). Through a questionnaire survey, a hypothetical market for a non-market good or service (e.g. culturally significant fish or local recreation) is created, usually by giving a detailed description of the non-market benefits (Mitchell & Carson, 1989). In the simplest scenario, respondents are asked how much they would be willing to pay for a change from the current situation to a hypothetical future situation. However, many researchers have raised serious concerns about the ability of CVM studies to derive valid estimates of economic value (see Kahneman & Knetsch, 1992 for a discussion of some of the limitations of CVM).

The discrete choice experiment (DCE) is another stated preference research method that addresses a number of the difficulties traditionally associated with contingent valuation methods. Rather than simply asking respondents how much they are willing to pay for a single improvement in a given non-market good, a DCE forces respondents to repeatedly choose between complex, multi-attribute profiles which describe various changes in non-market benefits at a given cost (e.g. a change in tax paid). Discrete choice modeling has been used to estimate the value of a wide variety of environmental goods and services, including recreation activities (Adamowicz, Louviere & Williams, 1994), caribou preservation (Adamowicz, Boxall, Williams & Louviere, 1998), environmentally sensitive areas (Hanley *et al.*, 1998), forest management (Hanley, Write, & Adamowicz, 1998), wetland quality (Morrison, Bennett, & Blamey, 1999), and desert vegetation (Blamey, Bennett, Louviere, Morrison, & Rolfe, 2000).

Discrete Choice Experiment

The discrete choice experiment is a stated preference evaluation technique that originated in transportation research, and has been applied extensively in the fields of applied decision making and market research (Adamowicz *et al.*, 1998). In the past, so-called 'choice theory' was used to model actual behavior (revealed preference methods). When applied to the analysis of behavioral or preference information derived from evaluations of hypothetical profiles or choice sets, it is referred to as stated preference / choice modeling (Louviere *et al.*, 2000).[1]

In a typical DCE study, respondents are presented with a series of choice sets composed of two or more multi-attribute alternatives (one alternative is often the status quo). For each choice set, a respondent evaluates the alternatives and chooses a preferred option. The alternative options in each choice set are described using a common set of attributes, which summarize the important aspects of the alternatives. For example, a choice experiment on automobile preferences might include attributes that describe cost, fuel economical, and safety features. Each attribute is defined by at least two distinct levels, which are varied systematically between the choice sets depending on the underlying statistical experimental design.

The choice preferences of all respondents are aggregated and analyzed using statistical methods based on choice theory. This results in utility or value functions for each attribute over the range of attribute levels used in the experiment. The part-worth utilities associated with each attribute level demonstrate their overall importance or contribution to the choices made by the survey respondents. In addition, ratios of utility coefficients indicate compensating marginal values between different attributes.

Principles of choice modeling

The theoretical basis for stated choice research lies in random utility theory. In this theory, the utility a person gains from a particular site or experience is described by the

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[1] Another common stated preference technique is conjoint analysis, which is based on the evaluation on individual profiles. Unlike discrete choice methods, conjoint techniques do not have a behavioural basis in random utility theory.

following utility function (sometimes referred to as a conditional indirect utility function):

$$U_{in} = V_{in} + \varepsilon_{in} . \tag{1}$$

The utility gained by person *n* from alternative *i* is made up of an objective or deterministic and observable component (*V*) and a random, unobservable component (ε) (Adamowicz *et al.*, 1994; 1998).

The observable component of utility (*V*) can be expanded as follows:

$$V_{in} = \mathrm{ASC}_i + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k . \tag{2}$$

ASC_i is an alternative-specific constant that represents the "mean effect of the unobserved factors in the error terms for each alternative" (Blamey, Gordon & Chapman, 1999, p. 341). The X_k values are associated with each attribute level used in the choice experiment, while the β_k coefficients are included to capture the corresponding part-worth utility associated with each attribute level for all *k* attributes.

An individual will choose alternative *i* over alternative *j* if (and only if) the total utility associated with alternative *i* is greater than that of the alternative *j* or $U_{in} > U_{jn}$. The probability that person *n* will choose alternative *i* over alternative *j* is given by the equation:

$$\mathrm{Prob}(i|C) = \mathrm{Prob}\{V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}; \forall j \in C\} , \tag{3}$$

where *C* is the complete set of all possible options from which the individual can choose.

The unobservable component ε, is often referred to as a 'random error component'. It is commonly assumed to be type I or Gumbel distributed and to be independently and identically distributed (McFadden, 1974).

If the ε term is assumed to be Gumbel-distributed, the probability of choosing alternative *i* can be calculated by the equation (McFadden, 1974):

$$\mathrm{Prob}(i) = \frac{\exp^{\mu v_i}}{\sum_{j \in C} \exp^{\mu v_j}} , \tag{4}$$

which represents the standard form of the multinomial logit model (MNL).

The MNL is the most common form of model applied to the analysis of discrete choice data, due to its robustness and the simplicity associated with calculating the probabilities (Louviere *et al.,* 2000). However, other models are also regularly used in stated choice research (e.g. the probit model). An important characteristic of the logit model is that choices are assumed to be independent of irrelevant alternatives (IIA). This means that "the ratio of choice probability for any two alternatives is unaffected by addition or deletion of alternatives" (Carson *et al.,* 1994, p. 354). In other words, the alternatives are assumed to be independent.

The β_k coefficients (or part-worth utilities) are derived by fitting the choice model to the observed data on the stated choice probabilities (aggregated over all respondents) and the experimental design used to define the attribute levels seen by respondents for each choice set. Choice models are usually estimated using maximum likelihood analysis.

To calculate efficient part-worth utilities, the choice experiments are normally designed to ensure orthogonality[2] of attribute levels both within and between alternatives. A full factorial design, where all main effects and interactions are orthogonal represents one extreme. However, full factorial design plans require individuals to evaluate an unrealistic number of choice sets (i.e. every possible combination of attribute levels), even in cases where the total number of attributes is small. Therefore, researchers typically make trade-offs between the ability of a design plan to estimate all possible interactions and the necessity to limit evaluation to a reasonable number of choice sets by employing a fractional factorial design plan. Fractional factorial designs typically permit the orthogonal estimation of all main effects and at least some interactions between the attributes.

Survey Development for Guam

The choice experiment survey for this study (on non-market values associated with Guam's coral reefs) was developed through a series of discussions with experts and focus groups, as well as pre-tests in the field. The main purpose of these activities was to identify and describe the most relevant attributes and levels associated with the non-market values of Guam's coral reefs. Specifically, the values that Guam's residents associate with recreational use, non-commercial fishing, culturally significant fish species, water pollution, and reef management options were explored. The final attributes and attribute levels chosen for the choice experiment are summarized in Table 3.1. They reflect the need to describe possible changes in the indirect non-market benefits associated with the reefs, as well as an appropriate payment vehicle. This allows the estimation of dollar values for each non-market benefit.

The alternative options, which appear in the choice sets were derived by combining, the levels associated with the six variables. This was done using a fractional factorial design plan. For this survey, a fractional factorial representation of a resolution III main effects design (Addelman, 1962) required 36 replications, which were evenly divided between 9 versions. As a result, each respondent was only required to evaluate four choice sets. Each choice set (see Figure 3.1) contained two hypothetical alternatives (1 and 2), and one additional scenario describing the status quo. Respondents were asked to indicate their preference between the three alternative options.

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[2] In an orthogonal design, the attribute levels are uncorrelated with any other attributes, thus ensuring that the part-worth utilities measure only the intended attribute and are not confused with other attributes.

Table 3.1 Attributes and attribute levels used for the discrete choice experiment

Attribute	Level description
Reef Recreation – Number of recreation areas provided by Guam's coral reefs	20% less No Change 20% more
Fish Catch – Reef fish and seafood caught during the average fishing trip is enough for …	One meal One meal and sharing One meal, sharing and selling
Culturally significant Fish – The amount of culturally significant fish (e.g. manahak – baby rabbit fish and ti'ao – baby goatfish)	20% less No Change 20% more
Fishery and Reef Management Practices –	None (outside the MPAs) No night scuba spear fishing No small sized gillnets No night scuba spear fishing and no small sized gillnets
Pollution from Land – Change in the amount of pollution discharged onto the reef (e.g. sediment, sewage)	20% less No Change 20% more
Income Tax – Change in the amount of income tax that you pay on a yearly basis.	$40/year less $20/year less No Change $20/year more $40/year more $60/year more

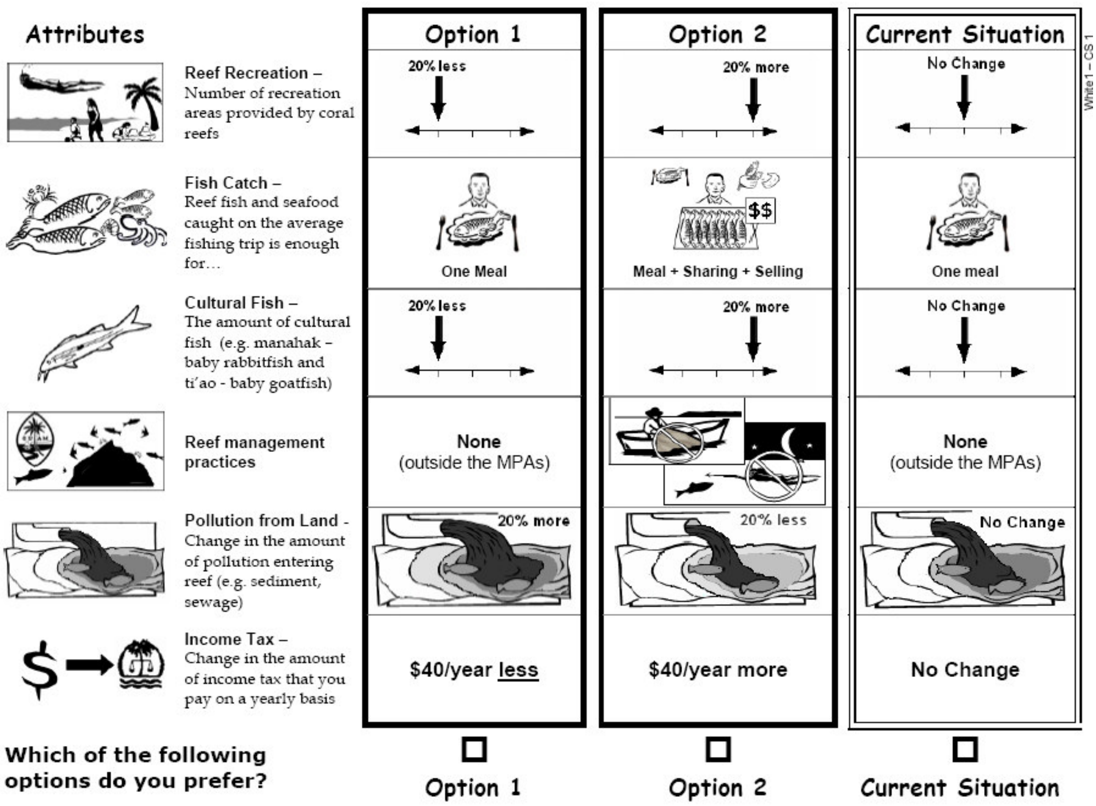

Figure 3.1 Example of a choice set

The written descriptions of the attributes and levels were supplemented with pictograms and graphic scales. This helped to make information processing easier for the respondents, particularly for those who were semi-literate or illiterate. For each of the nine versions, four experimental choice sets and one common choice set (the same for all versions) were printed on a specific color of paper. Each choice set was printed on a separate sheet of paper and laminated; the nine versions were then bound in small spiral binders, one for each interviewer. The choice experiment was conducted as part of the larger household survey (Chapter 2). As a result, each interviewer carried a full set of choice cards and went through these different versions (using one version per respondent). The version and the respondent's choices were recorded on a response sheet. The interviewers were trained prior to data collection on i) the basic principles of choice experiments, ii) how to properly administer the choice experiment without introducing bias into the results, and iii) how to help respondents understand the tasks. Each interviewer was also provided with a detailed interview protocol to ensure that survey administration and data collection were completed in an efficient and consistent manner.

Following the completion of the surveys, the 400 responses were coded in a spreadsheet. Analysis of the DCE was performed with econometric software called LIMDEP v.7 (Greene, 1998). Parameter estimation was based on a multinomial logit model following maximum likelihood estimation.

3.3 Results

General Model Development

The final model was coded as a mix of dummy coding and linear coding. Even though all variables were specified at 3 or 4 levels, it was possible to apply linear coding to attributes with numeric variable specifications (i.e. reef recreation, culturally significant fish, pollution, and income tax). The fish catch and reef management attributes were kept dummy coded. Table 3.2 presents the MNL parameter coefficients, their standard errors, and *t*-values for each attribute over the entire survey sample. Significant coefficients ($p<0.05$) are marked in bold. The results for the overall model are also presented graphically in Figure 3.2. The choice experiment contained two generic options (A or B), and a base alternative (status quo). Because of the generic nature of the design, all estimates, including the intercepts for A and B, were combined into single generic estimates. The intercept estimate for the options is not significantly different from that of the baseline alternative. This indicates that, all else being equal, the alternative options would be chosen around the same number of times as the baseline.

For the attributes estimated with continuous value functions - namely recreation, culturally significant fish, pollution, and income tax - a linear equation provided the best fit. All four linear coefficients were significant and had the correct sign. For example, there is a negative marginal utility associated with increasing income tax. None of the quadratic estimates were significant and were dropped from the final model. The linear estimate of the coefficient represents the slope of the utility function associated with each attribute or, in other words, the change in marginal utility per unit change in the attribute value. Note that the exact interpretation of the coefficients depends on the coding used in the model. For example, the recreation utility coefficient is associated with a unit change of 20% in the level of recreation, because a factor of 20 was used to develop the linear coding.

For the dummy coded attributes 'fish catch' and 'reef management', part-worth utilities were derived for each attribute level. With dummy coding, the part-worth utility coefficients are normalized to a base value, which is usually the lowest or zero level. In other words, part-worth utility coefficients are interpreted relative to the base value.

For fish catch, the level associated with having enough fish to provide one family meal with some fish left over to share with others was significantly preferred over the status quo level (just enough fish to provide one meal). Although the utility associated with having enough fish to share and to sell was positive, the coefficient was not significantly different from the status quo value. The strong preference for the sharing aspect of fish catch is an indication of how important sharing is for Guam's people.

The results of the reef management attribute indicate that, overall, the residents of Guam are supportive of reef management practices; however, the only management scenario that was significantly preferred over the current situation was the combination of a ban on small sized gillnets and night scuba spear fishing.

Table 3.2 DCE - Main Model, all respondents (significant t-values in bold)

Attributes	Level	Coefficient	SE	T-Value
	Status Quo	0.000		
	Alternatives	0.144	0.145	1.0
Reef Recreation	Linear	0.110	0.048	**2.3**
Fish Catch	One meal	0.000		
	One meal + sharing	0.227	0.096	**2.4**
	One meal + sharing + selling	0.089	0.098	0.9
Culturally significant Fish	Linear	0.107	0.049	**2.2**
Fishery & Reef Management Practices	None (outside the MPAs)	0.000		
	No night scuba spear fishing	0.103	0.092	1.1
	No small sized gillnets	0.138	0.101	1.4
	No night scuba spear fishing and No small sized gillnets	0.369	0.122	**3.0**
Pollution from Land	Linear	-0.524	0.044	**-11.9**
Income Tax	Linear	-0.126	0.059	**-2.1**

Model Statistics:

N=400

$Rho^2 = 0.07$, $Rho^2adj. = -0.16$
Log Likelihood (0): -1683.07
Parameter model: -1568.02

The coefficients in Table 3.2 are also referred to as part-worth utility values associated with each attribute, and express the "marginal utility", or in other words, the relative preference change between attribute levels of the same attribute. That interpretation is clear and straightforward for the categorical variables of fish catch and reef management practices. The other variables were treated with numeric levels (i.e. 20% less, same, 20%

more), and in these cases a simple linear estimate was derived. A quadratic function was also tested for each variable, but was not significant in any of the cases.

For ease of interpretation, these coefficients can be graphed (Figure 3.2). The ranges of the part-worth utilities shown in Figure 3.2 indicate that the pollution attribute was the most influential. This result is not surprising given that a wide variety of pollution issues have received significant media attention in Guam. These include regular contamination from broken sewer outflows, sediment run-off from intentionally set fires, military waste, and the superfund site associated with the old waste dump.

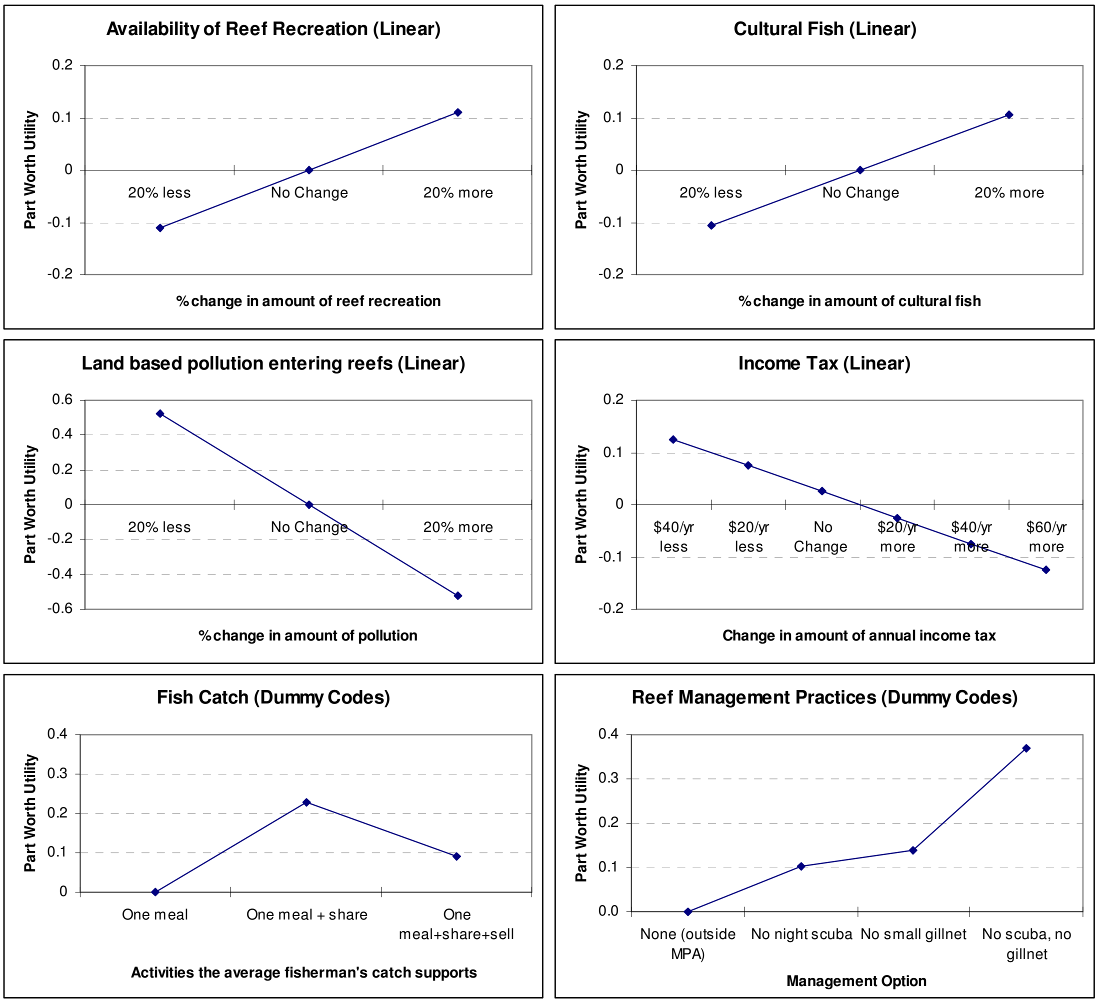

Figure 3.2 Utility estimates for DCE attributes

Economic Values for Non-market Attributes

As stated previously, one of the primary motivations for using the choice experiment was to provide a method for valuing non-market benefits associated with Guam's coral reefs. The trade-offs made by respondents between the monetary tax attribute and the other non-monetary attributes in the choice experiment, indicated the compensation required for changes in the non-market values. The marginal willingness to pay for an increase in the non-market attribute (β_i) can be calculated using the formula β_i / β_{tax} .

Using this method, economic values were derived for each of the five non-monetary attributes in the choice experiment (Table 3.3).

Care must be taken to use an appropriate baseline when comparing the WTP between attributes that are measured on a per unit basis (e.g. recreation, culturally significant fish, and pollution) and those measured by individual attribute levels (e.g. reef management and fish catch). For example, the WTP associated with a 20% increase in recreation is $44.60 (20*$2.23), which is comparable to the WTP to ban night scuba spear fishing. In addition, the WTP values are correct only when all other attributes are set at their respective base values. Since the choice model is based on a logit curve (non-linear), an overall WTP for a combination of changes (e.g. increased recreation and culturally significant fish at the same time) cannot be estimated by simply adding these individual WTP values across different attributes. For multiple attribute changes, WTP estimates can be derived using Equation 5 (Bennett and Blamey, 2001):

$$CS = \frac{-1}{\beta_{tax}}(V_0 - V_1)\,, \qquad (5)$$

where *CS* is the compensating surplus, β_{tax} is the linear utility coefficient on income tax and *V* is the observable component of total utility (e.g. Equation 2).

Table 3.3 WTP values for attributes in the DCE

Attribute	Economic Value	Units
Reef Recreation	$2.23	$/% increase
Culturally significant Fish	$2.15	$/% increase
Fish Catch:		
- one meal and sharing	$91.68	Relative to one meal
- one meal and sharing and selling	$31.83*	Relative to one meal
Reef Pollution	$10.40	$/% increase
Reef Management Options:		
- No night scuba spear fishing	$42.49*	Relative to None
- No small sized gillnets	$56.35*	Relative to None
- No night scuba spear fishing and no small sized gillnets	$148.36	Relative to None

* The coefficients on which these values are based are not significant

3.4 Discussion and Conclusions

Guam's coral reefs provide important cultural, recreational, and non-commercial fishery values that are not easy to measure using traditional economic methods. Individuals may value or enjoy various aspects of the reef or services it provides, but may never have to pay directly or indirectly for these benefits. Furthermore, these non-market values may be difficult to define and harder yet to quantify. However, it is extremely important to include non-market values in economic assessments in order to ensure that governments and policy makers are aware of the full value associated with natural assets such as coral reefs.

The discrete choice experiment implemented for this research project investigated three important non-market benefits associated with Guam's coral reefs: local recreational use, abundance of culturally significant fish species, and non-commercial fishery values. In addition, a pollution attribute and a reef fishery management attribute were included in the choice experiment as two factors affecting reef health. The pollution attribute measured preferences for controlling land based sources of pollution (including sedimentation, run-off, and sewage outflow), while the reef management attribute measured preferences for eliminating destructive fishing practices. Income tax was included as the monetary variable in the choice experiment to provide a suitable payment vehicle for willingness to pay calculations.

The results of the DCE indicate that significant economic values are associated with the three non-market benefits included in the survey. Guam's residents appear to place a similar value on the reefs' ability to provide local recreational benefits and supply culturally significant fish species. In addition, the results indicate that maintaining reef fish and seafood stocks at a level that can support the culture of food sharing is very important.

Although Guam's residents generally support the ban on some of the more exploitative fishing methods (such as night scuba spear fishing), they are more concerned about the effects of pollution and managing pollution as a threat to the reefs. The importance of the pollution attribute is not surprising since pollution has negative effects on both consumptive (e.g. fishing) and non-consumptive benefits (e.g. snorkeling, beach use) of coastal waters. In addition, many residents are likely to have had some exposure to the negative effects of pollution: several recreational and fishing areas around Guam were recently subjected to a negative fisheries advisory due to contamination.

Overall the results of this study demonstrate that the Discrete Choice Experiment is a useful tool for valuing non-market benefits and can be used in a complementary manner with more traditional economic valuation methods. The DCE is an efficient means of collecting information, since choice tasks require respondents to simultaneously evaluate multi-attribute profiles. In addition, economic values are not elicited directly but are inferred by the trade-offs respondents make between monetary and non-monetary attributes. As a result, it is less likely that WTP information will be biased by strategic response behavior. A further advantage of the DCE is that research is not limited by pre-existing market conditions, since the levels used in a choice experiment can be set to any reasonable range of values. As such, the DCE can also be used as a policy tool for exploring proposed or hypothetical futures or options (for example, in a decision support tool based on the results). Finally, and perhaps most importantly in the context of non-market valuation, choice experiments allow individuals to evaluate non-market benefits described in an intuitive and meaningful way, without being asked to complete the potentially objectionable task of directly assigning dollar figures to important values such as culture.

4. Total economic value

4.1 Introduction

The main objective of this study is to determine the economic value of the marine ecosystems of Guam. At the core of this economic value are the various coral reef ecosystem functions, which translate into reef-associated goods and services (benefiting Guam's society). As shown in Table 4.1, each of these goods and services has associated economic benefits. *Goods* provided by coral reefs can be sub-divided into renewable resources (fish, seaweed, etc.) and non-renewable goods (such as sand mined from reefs etc.). In other areas of the world, coral mining for lime and building materials is also practiced, but this does not occur anymore in Guam. The *services* provided by coral reefs are categorized in general into: (i) physical structure services (e.g. 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 (e.g. nitrogen fixation); (iv) information services (e.g. climate record); and (v) social and cultural services (e.g. aesthetic values, recreation and gaming).

Table 4.1 Goods and services of coral reef ecosystems

Service	Products
	Goods
Renewable resources	Seafood 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 sea grass 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)

The goods and services discussed above have associated economic values. The value of the sum of compatible uses of these goods and services together 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 (e.g. preservation, tourism, multiple use etc.). In the coming sections, we demonstrate the calculation of the TEV of coral reefs in Guam.

4.2 Methodology

Economic valuation is a tool that nowadays is commonly used to evaluate the economic importance of coral reefs to society. The methods vary, depending on the type of attributes valued. In this section we briefly introduce the concept of economic valuation of coral reefs by describing i) values, ii) goods and services, and iii) valuation techniques applied in this project. A more elaborate explanation of the methodological background of coral reef valuation can be found in Cesar (2000) and Gustavson *et al.* (2000).

Value types

There are many ways of looking at the value of coral reefs. In this Section we will describe four of these. These include:

- Market and non-market values
- Use and non-use values
- Producer and consumer surplus values
- Economic and financial values

Market and non-market values

A fundamental way to categorize the economic value of coral reefs is the distinction between market and non-market goods. The value of market goods, such as the price of fish or seaweed, can be directly observed from markets in the economy. These values are therefore relatively easy to value in monetary terms. Non-market goods, such as beach visits and snorkeling at a coral reef, are not directly traded in the market. Similarly non-market services from coral reefs, such as coastal protection and sequestration of carbon dioxide, are generally not directly reflected in market prices. Non-market goods and services therefore require special valuation techniques to determine its economic value. Throughout this study we will attempt to distinguish between market and non-market goods.

Use and non-use values

As shown in Figure 4.1, the TEV of coral reef ecosystems can be sub-divided 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 include, for example, the biological support reefs provide in the form of nutrients. Another example is the coastal protection value that coral reefs provide. Non-use values consist of option, bequest and existence values. The option value can be seen as the present value of potential direct and indirect uses of the coral reef ecosystem. An example is the potential for 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 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 an ecosystem is of value 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 4.1 Sub-division of the total economic value of coral reefsConsumer and producer surplus

From a theoretical perspective, the Total Economic Value (TEV) is defined as the sum of the producer and consumer surplus. To illustrate the meaning of these terms, an example for reef-related recreational benefits has been shown in Figure 4.2. The supply curve is positively sloped 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 snorkelling or diving.

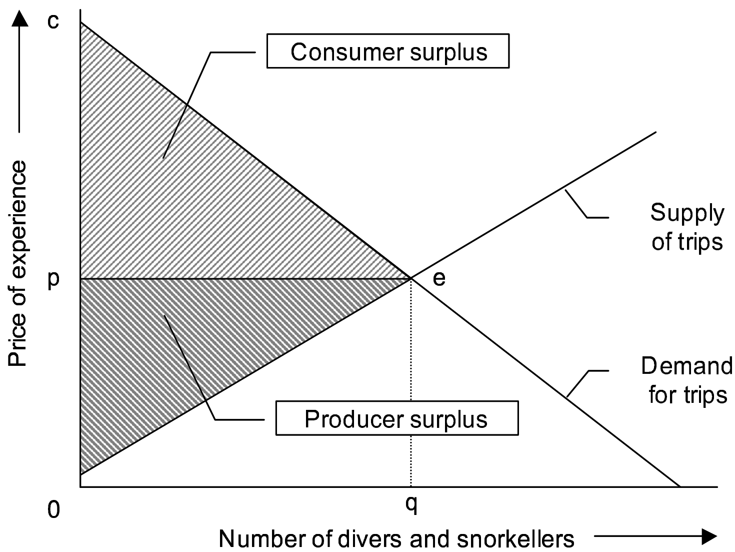

Figure 4.2 Conceptual composition of the recreational benefits

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 Guam is equal to the sum of the consumer and the producer surplus.

To calculate the consumer surplus, (i.e. the amount the visitors would have been willing to pay (WTP) in addition to the actual payment to enjoy the Guam reefs), we applied benefit transfer from studies conducted in other regions. Calculating the producer surplus is a more complex issue. Formally, one would need to ask producers their additional WTP to produce an additional service or good. However, because such estimates are not available for the marine-related industry in Guam, we calculate the producer surplus by multiplying the value added of a marine related good with the number of goods sold. This implies that we aggregate the financial 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. The expenditures indirectly related to the marine experience include hotel costs and travel costs.

Financial and economic values

It is important to understand the difference between the financial and the economic value of coral reefs. The *financial* value concentrates on the cash flows that are linked the use values of coral reefs. This involves the value added from fisheries, the tourist industry and the dive and snorkeling operations in Guam. It is common to also account for the secondary financial effects of these revenues on the economy of Guam: the so-called multiplier effect. This accounts for the effect that expenditures in the coral reef related industry have on other sectors in the Guam economy. The *economic* importance of coral reefs, the TEV, includes both market and non-market effects and therefore has a broader interpretation of value. Another difference between the economic and the financial value is the fact that the multiplier effect is not accounted for in the TEV (see Figure 4.3). In this study, the prime focus is on determining the TEV.

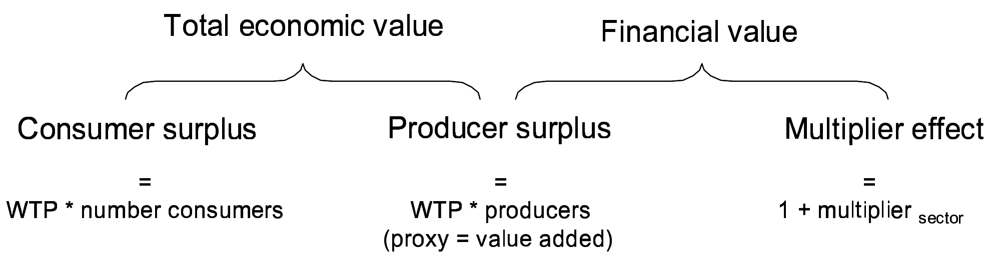

Figure 4.3 Difference between economic and financial value

Selected goods and services

Resource and budget constraints call for a selection of the most important goods and services for actual economic valuation, and thereby inclusion in the calculated TEV of Guam's coral reefs. The following goods and services were quantified in order to obtain a 'lower boundary' estimate of the TEV:

- *Tourism*: Tourism is big business in Guam. Although not all tourism depends directly on coral reefs, coral reefs often form an important marketing tool to attract foreign visitors. Therefore, much coastal tourism depends to an extent on the quality and quantity of the coral reefs in Guam.
- *Diving and other direct recreational uses*: The recreational use of coral reefs relates to reef-related activities (such as diving, snorkeling, submarines, and surfing) enjoyed by both tourists and residents.
- *Fisheries*: Commercial, subsistence and recreational fishing are all important for Guam's economy. Traditionally, fishing has been a central activity within local communities, with an important cultural value.
- *Coastal Protection*: Coral reefs act as wave breakers and thereby fulfill an essential function in terms of coastal protection. The valuation of the impact of decreased protection (due to a variety of threats) depends on current and/or potential economic activities in the area.
- *Amenity value and property value:* The beautiful views of shallow coastal waters from beachfront properties suggest that part of the amenity value of these properties can be attributed to the presence of coral reefs. Degradation of the reefs makes beachfront properties less attractive, reduces occupancy rates in hotels, etc. (Gustavson *et al.*, 2000).
- *Cultural services*: Native Guam communities have traditionally had a special cultural attachment to the ocean and its reefs. Most residents share these views to some extent; coral reefs and the sea are an important part of daily life in Guam. Though not very tangible, this is a clear 'service' that reefs provide to residents.
- *Biodiversity*: Guam is home to a great number of endemic species and many professionals are attracted by this biodiversity. For example, some pharmaceutical companies are interested in exploring bio-prospecting. In this study, we will attempt to determine a specific value of biodiversity through estimates of expenditures by government agencies and NGOs on coral reef research in Guam.

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 reef ecosystems. Standard techniques in micro-economics and welfare economics rely on market information to estimate values. However, for most externalities inherent to environmental issues, standard techniques such as using market prices cannot be employed. Table 4.2 lists the most common techniques used for valuing the goods and services of coral reef ecosystems.

Three general categories are identified: (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 which ask individuals about their willingness to pay (WTP) for the environmental good directly (by using structured questionnaires). WTP is defined as the maximum amount of money a person is willing to pay to obtain a good or service.

Table 4.2 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
- Damage Costs (DC)	Coastal Protection
- Compensation payments (CP)	Fisheries
Revealed preference techniques	
- Replacement costs (RC)	Coastal protection
- Travel-cost approaches (TC)	Tourism/recreation
- Property-value and other land-value approaches (PV)	Amenity value
Stated preference techniques	
- Contingent valuation methods (CVM)	Cultural services, etc. biodiversity
- Choice Experiment (CE)	Cultural services, etc. biodiversity

Source: Adapted and shortened from Dixon (1990), Barton (1994).

In this study we apply five main valuation techniques. These techniques are the Effect on Production (EoP); Replacement Costs (RC); Damage Costs (DC); Travel Costs (TC); and the Choice Experiment (CE). These methods are more elaborately addressed in later sections.

4.3 Fisheries

Since ancient times, fish has been the primary source of protein for the islanders of Guam. Moreover, fishing was and still is an important part of Guam's culture. In the past, subsistence fishing provided Guam's residents with an ample supply of fish. Most of the catch was consumed by fishermen's families or shared with the community. Recent decades have seen the introduction of modern fishing techniques and the increased importance of non-seafood items in residents' diets. This has caused a change in Guam's fisheries, from traditional subsistence fisheries to the more modern subsistence, commercial and recreational fisheries.

Despite the resulting decline in fish stocks, the reefs of Guam provide an important habitat for fish. Generally, reefs create significant opportunities for feeding, breeding and refuge from predation for both fish and invertebrates. As a result, reef complexity is directly linked to reef biomass: reef habitats with greater structural complexity have higher primary productivity (e.g. Adey & Steneck 1985). This link between physical complexity of the reef substratum and fish populations is confirmed by Luckhurst and Luchhurst, 1978; Gladfelter *et al.,* 1980; Carpenter *et al.,* 1981; Sano *et al.,* 1984; Roberts and Ormond, 1987; Hixon and Beets, 1989; and Galzin *et al.,*1994.

To determine the value of reef-related fisheries, both the direct and indirect value of reef-fishing should be taken into account. The indirect value refers to the cultural and recreational importance of fishing in Guam. This valuation exercise is described in the choice modeling section. The direct value of reef-related fisheries refers to the market value of the fish catch provided by the coral reefs of Guam.

Contemporary fishing methods in Guam include trolling, hook and line, net fishing, spear fishing, hook and gaff, and gleaning. An overview of the importance of these techniques is provided in Figure 4.4. The most popular fishing method to catch bottom fish in Guam is hook and line. This technique includes the use of i) handlines ii) rod and reel with lures and iii) baited hooks. Spear-fishing has undergone great changes with the advent of modern equipment, evolving from the use of handmade spears and free-diving to spear-fishing with scuba gear. Because of the highly selective nature of these methods, spear-fishing targets larger species of fish, such as parrotfish.

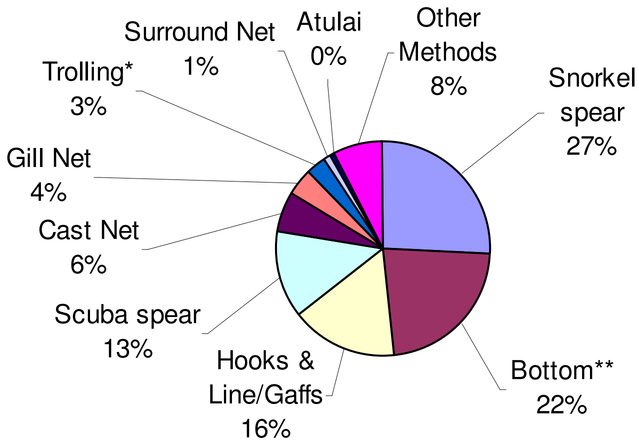

Figure 4.4 Fishing techniques used in Guam in 2003 (Source: DAWR, website)

Notes:

* Percentage of reef-associated fish caught by trolling is 1.82% of total trolling amount

** Percentage of reef-associated fish caught by bottomfishing is 81.44% of total bottomfishing amount

To determine the direct value of reef-related fisheries, both inshore and offshore reef fishing activities need to be determined. For this purpose, the data sources of DAWR were analyzed. Each year DAWR conducts interviews with fishermen to extract data on catch, gear use and effort. These data are then used to extrapolate total annual catches in Guam. For inshore fishing this is a straightforward calculation because most inshore fishing concerns reef-fish.

For offshore fishing this is more complicated because 'offshore' includes anything caught by a boat and offloaded at one of the marinas. For example, a boat fishing right over the reef and catching only reef fish is still grouped under 'offshore'. By accounting for the reef-fish caught 'offshore' only, the value of reef fiching in the overall fishing activities in Guam was determined. For example, in 2003, a total of 228,532 kg of fish were caught by trolling, and a total of 38,372 kg were caught by bottom-fishing. Of these amounts, 4,184 kg of the fish caught by trolling were reef fish (1.83%) while for bottom-fishing, 31,252 kg were reef fish (81.44%). Using the same approach, non-reef associated fish are subtracted from inshore fisheries catch.

The result of this method for the period 1992-2003 is shown in Figure 4.5. With on average 75 to 100 tons of reef-associated fish, inshore fishing accounts for the main share of the reef-associated fisheries. However, it is also the most erratic source of fish. Offshore fisheries remain relatively stable at around 50 tons of reef-associated fish per annum.

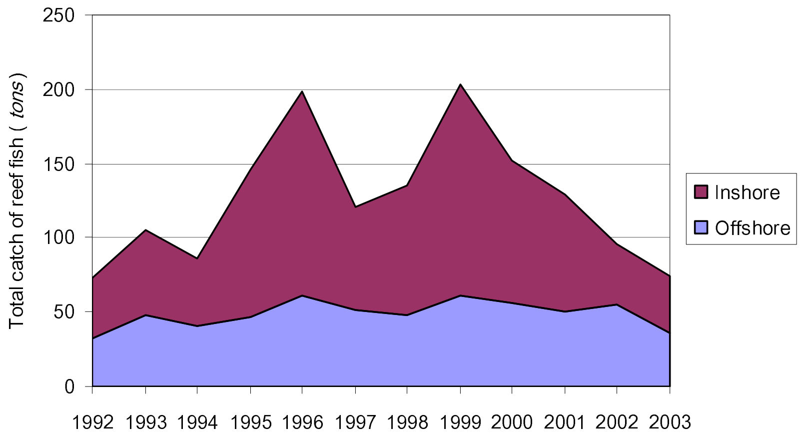

Figure 4.5 Total inshore and offshore catch of reef-associated fish

The general understanding with regard to the ecological state of fisheries in Guam is that fish stocks are gradually being depleted.[3] Figure 4.5 does not reveal such a trend in fish catch. However, when reviewing catch per unit effort (CPUE) data, some patterns become visible (see Figure 4.6). The longest time series available for CPUE data (for fisheries in general in Guam) runs from 1985 until 1998. This series shows a highly significant negative trend ($r^2 = 0.73$), which implies an annual decline of around 0.04 kilograms per gear per hour. Similar declines were noticeable in the inshore fisheries time series, which are based on interviews with fishermen. It should be noted, however, that due to the limited length of the time-series, the significance of this trend is considerably lower in reality. This also holds for the offshore fishing trends.

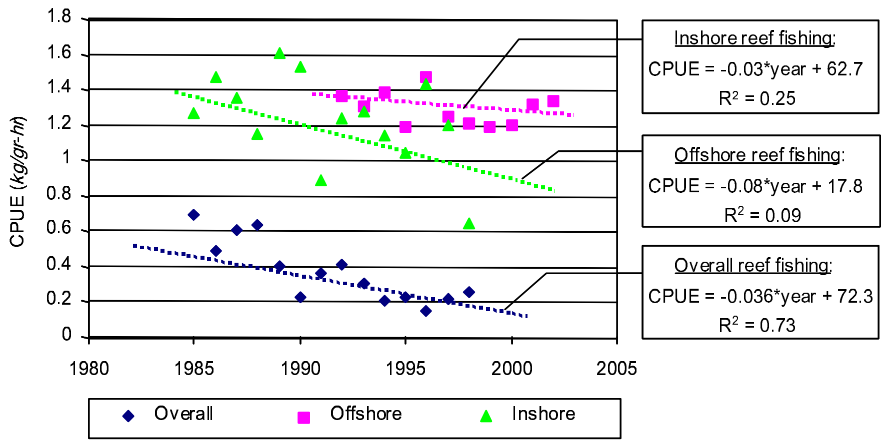

Figure 4.6 Catch per unit effort for inshore and offshore fishing (in kg/hour gear use)

3 It is also claimed that with the implementation of the MPA's in 2001, fishermen are forced into more concentrated areas, which in turn could deplete fish stocks if it is already under pressure from land use issues. However, it is difficult to determine the exact share of the reduced catch resulting from fishing restrictions at the current MPA sites.

Figure 4.7 shows the gear use time for the period 1992 to 2003, although the period is too short to draw definite conclusions. There seems to be a negative trend, particularly from the late 1990s until now. This trend is partly confirmed by DWAR who reported a sharp decline in fishing time since the late 1990s (DAWR, website).

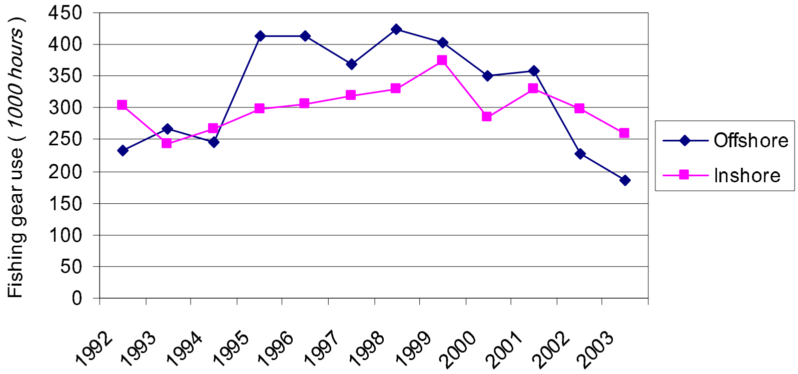

Figure 4.7 Fishing gear use for reef-associated inshore and offshore fishing (hours of gear use)

We also took a closer look at the different techniques used in Guam. As shown in Figure 4.8 (in which 3-year averages have been taken) snorkel spear fishing and hook and line fishing account for more than 50% of the fish caught. The increase in snorkel fishing in the last 10 years has probably been partly caused by the decline in gill netting and scuba spear fishing. Also, the use of cast nets has diminished in popularity.

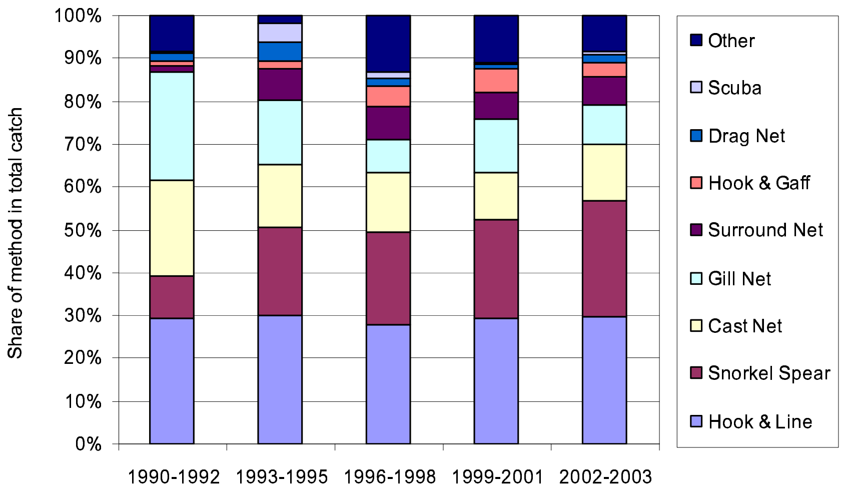

Figure 4.8 Change over time of the relative importance of the various fishing methods used in Guam

Source: DAWR, website.

The market for near shore reef fish has increased in Guam, especially given the diverse cultures that eat fish as a primary source of protein. With the influx of new people and the desire for local fresh fish, the market continues to expand. Potentially, the decline in CPUE in combination with an increasing demand for fish may be reflected in higher fish prices. Figure 4.9 shows how average fish prices in Guam have gradually increased over the last 25 years. Recently, prices have been as high as US$8-10 per kilogram for whole reef fish (DAWR, website).

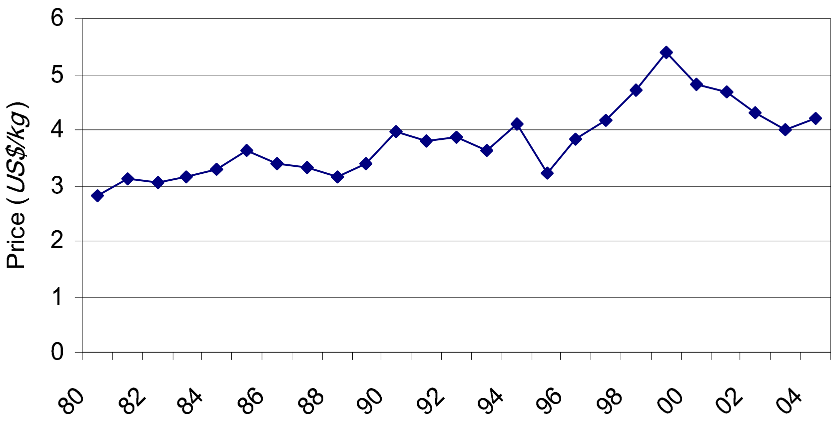

Figure 4.9 Price development of commercial fish in Guam (in US$/kg)
Source: PIFSC, 2005.

The economic valuation of the direct (market value) of fishery in Guam is a relatively straightforward exercise. The direct value of fish can be calculated according to the cost price of fish, which in turn is assumed to be around 90% of the market value of fish sold in Guam. Based on the most recent 5-year average price reported in Figure 4.9, the market value we adopt amounts to US$4.63 per kg of fish. We assume that the average annual catch of reef-associated fish amounts to around 130 tons, which is also a 5-year average. This automatically leads to a direct (market) reef-associated fish value of US$ 0.544 million (i.e. 90%*131 tons*US$4.63).

A much more important value of fishery activities in Guam is the non-market value of these, mostly, recreational activities. This is the “cultural” value of the activity itself, representing a number of services, such as the tradition of fishing, the bond with fellow fishermen, the exposure to the ocean and nature in general, and the possibility of sharing fish with friends and family.

The cultural (non-market) component of the fishery value has been determined in the choice experiment described in Chapter 3, in which the value changes have been analyzed, using different scenarios. In scenario 1, we assume a situation in which we take “fish catch only” as the starting point and we move from the original level of sharing, ‘one meal’ only, to a sharing level of 'meal and sharing'. In this scenario, the estimated compensating surplus amounts to US$91.68 per household per year. In scenario 2, we combine 'one meal and sharing' and '20% more culture fish'. In this scenario, the compensating surplus amount to US$134.74. Scenario 3, which is based on the change of cultural fish alone, provides the lowest estimate of the cultural value of fishing. The derived value amounts to US$ 43.06 per household per year.

The above marginal estimates provide sufficient information to determine an upper- and lower bound value of the cultural (non-market) importance of fishing in Guam. Given the fact that both variables (i.e. the type of fish caught and the level of sharing of the catch) are determinants of the cultural value of fishing, we can conclude that Scenario 3 is the most conservative estimate while Scenario 2 provides the most optimistic scenario. Given the fact that the number of households in Guam is 44,359 (see Table 4.3), we can determine the aggregated maximum and minimum value of the cultural importance of fishing. The minimum value is based on the lower estimate of US$43 per household in combination with the assumption that only those families that actively participate in fishing, benefit from fishing and sharing. This minimum value amounts to US$859,544. For the maximum cultural value, it is assumed that all households in Guam benefit from fishing and sharing in combination with the upper bound estimate derived in the choice experiment (i.e. US$135 per household). This maximum cultural fishing value is estimated to be almost US$6 million.

Table 4.3 Calculation of the cultural (non-market) value of fishing in Guam

Variable	Level	Unit
Guam population (2005) *	168,564	People
Household size in Guam (2005) *	3.8	Person per household
Number households in Guam (2005)*	44,359	Households
Minimum fishing household share	45%	Assuming only fishing households benefit
Maximum fishing household share	100%	Assuming all households benefit from sharing
Minimum annual value	43.06	US$/household
Maximum annual value	134.74	US$/household
Minimum cultural value	859,544	US$/year
Maximum cultural value	5,976,932	US$/year

* Source: U.S. Census Bureau, website.

4.4 Tourism

Tourism is the economic mainstay of Guam, with slightly over one million tourists visiting the island annually. This number has declined somewhat over the past few years as a result of the SARS epidemic, the Asian economic downturn, September 11th and the Iraq War. Between 1995 and 1997, annual visitors exceeded 1.3 million per year (Table 4.4). However, not only is the tourism industry in Guam dependent upon demand from a limited number of markets (such as Japan and Korea), it is also heavily influenced by fluctuations in airline seat capacity: typically over 99 percent of tourists enter the country by air. Tourist arrivals from South Korea declined dramatically when Korean Airlines suspended flights to Guam following the August 1997 crash of a Korean Airlines flight at Guam International Airport. By 1998, the combined effect of reduced seat capacity from South Korean markets, and the onset of the financial crisis in Asia, resulted in overall tourist arrivals dropping by 18 percent, while arrivals from South Korea dropped by 83 percent compared to 1997 levels.

Table 4.4 Visitor arrivals in Guam over time (period 1989-2003)

Year	Japan	Korea	Hong Kong	Taiwan	US/Hawaii	Total arrivals
1989	555,748	4,514	1,990	966	42,678	668,827
1990	637,569	7,645	2,161	2,189	51,544	780,404
1991	582,270	19,008	3,019	8,574	50,258	737,260
1992	676,659	39,121	8,608	12,443	59,558	876,742
1993	549,343	68,604	6,613	23,562	61,169	784,018
1994	773,349	118,538	6,889*	38,791	66,847	1,086,720
1995	996,219	186,264	8,643*	31,816	56,626	1,361,830
1996	1,028,673	194,585	7,000	20,096	35,395	1,372,566
1997	1,114,451	119,154	8,344	22,509	43,332	1,381,513
1998	975,402	20,268	7,906	20,545	41,875	1,137,026
1999	957,738	47,299	8,943	41,444	40,729	1,161,840
2000	1,048,813	87,070	9,050	39,451	41,075	1,286,807
2001	901,536	89,655	9,174	31,539	38,557	1,159,071
2002	786,867	128,307	8,444	19,500	33,233	1,058,704
2003	659,593	87,341	4,620	18,673	35,409	909,506
2004	906,106	89,924	5,156	24,157	46,159	1,159,881
*2005***	*965,299*	*131,538*	*3,546*	*21,990*	*49,034*	*1,274,043*

* Estimated

** Extrapolated on the basis of the first two quarters of 2005

Source: GVB 2000, Master Report

Guam receives mainly Asian visitors, with Japanese tourists comprising the majority. Most visitors stay for 4 days, with expenditures ranging from US$128 to $450 per person per day (See Table 4.5). The average length of stay is increasing slightly, driven in part by the "silver hair" guests (i.e. older visitors) and in part by wedding couples. Typically, the "silver hair" market is not constrained by annual vacation allowances and the newlyweds tend to spend their honeymoon on the island (Le Quesne, 2000).

Table 4.5 Details of visitors by nationality

Nationality	Length of Stay	Expenditure per day	Average Age male/female*	Share Male/ Female	Share Married/ Single
Japanese	3.7	US$128	33/30	45/55	59/41
Korean	3.6	US$441	32/29	53/47	83/17
Hong Kong	4.5	US$450	33/31	45/55	61/39
Taiwan	3.5	US$336	32/30	48/52	53/47
US / Hawaii	13.3	US$387	41/38	70/30	55/45

* Weighted average based on info for age groups (18-29), assumes the age group 60+ comprises ages 60-69, and excludes UNKNOWN ages.

Source: GVB 2000, Master Report

The heterogeneity of visitors varies substantially. The average spending according to nationality ranges from US$646 for Taiwanese to US$3,422 for US visitors. However, general economic developments and exchange rate fluctuations strongly affect the spending power of Guam's visitors. For example, the purchasing power of visitors from Japan was weakened considerably due to the depreciation of the Yen against the US dollar. Consequently, not only did room revenues suffer, but food and beverage revenues declined as wholesalers reduced the cost of holiday packages, offering more "no frills" packages (which excluded one or two meals). Guests were spending more of their food and beverage budget in cheaper outlets, including convenience stores.

Table 4.6 Average spending by nationality (in US$)

Nationality	Air Fare	Hotel	Food	Other	Total
Japanese	$331	$203	$176	$432	$1,142
Korean	$474	$293	$144	$84	$995
Hong Kong	$361	$242	$228	$545	$1,376
Taiwan	$250	$155	$209	$32	$646
US/Hawaii	$1,816	$747	$495	$364	$3,422
Weighed average	$392	$229	$185	$392	$1,197

Source: GVB 2000, Master Report

Importance of marine resources and coral reefs for tourism

With this overview of tourism in Guam, we can start to determine the role of marine resources in this industry. The main types of ocean-related recreation in Guam include scuba diving, snorkeling, jet skiing, kayaking and (wind)surfing. Although it is generally known that these activities are important in terms of revenue generation, it is difficult to quantify this (indirect) role. In the following paragraphs, we will try to estimate the extent to which marine resources contribute to the tourism industry in general.[4]

In the tourist exit survey, tourists expressed a variety of reasons for visiting Guam, with sun, sea, and sand eliciting a response from 40% of Japanese and Taiwanese respondents and 51% of respondents from Hong Kong (See Table 4.7). The weighted average of the motive "Sea, sun and sand" amounted to 37%. Scuba diving and water sports are also important reasons for tourists to come to Guam. Scuba diving and marine based activities account for 5% and 15% (respectively) of the reason why tourist chose Guam as their holiday destination.

It is not trivial to translate these estimates to reef-related economic values. Although scuba diving and watersports are obviously dependent on healthy reefs, the motive "sea, sun and sand" is not necessarily linked to the presence of healthy reefs. On the one hand, replenishment of the beach is dependent on fresh sand grains provided by coral reefs. Also, reefs provide safe swimming waters for the tourists. On the other hand, many of the people that indicate to come to Guam for reasons of "sea, sun and sand" have no clue what goes on below the water surface, not will they ever attempt to witness the beauty of the coral reefs of Guam.

Despite these uncertainties, we need to make an assumption regarding the extent to which these motives are linked to coral reefs. The minimum share with coral reefs is around 19.8% (i.e. 5% for scuba and 14.8% for other marine activities). The maximum link amounts to 37.1% (i.e. sea, sun and sand). By taking the average of these upper and lower bound estimates, we will assume that approximately 28.5% of the tourist revenues are marine-related.

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4 It should be noted that some watersports activities can also be destructive to the coral reef ecosystems. However, these adverse impacts are not subject of this study.

Table 4.7 Motivation for visiting Guam (% of Survey Respondents)

Nationality	Scuba diving	Marine activities*	Sea, Sun, Sand
Japanese	5	16	40
Korean	2	6	18
Hong Kong	15	30	51
Taiwan	13	21	40
US/Hawaii	8	2	11
Weighed average	5.0	14.8	37.1

* Non Tour Package. Marine activities involve glass bottom boats, snorkeling, dolphin watching.

Source: GVB 2000, Master Report

Tourist expenditures related to coral reefs extend much further than the direct revenues gained from water sports activities, such as diving and snorkeling. The presence of beautiful coral reefs and clean beaches is a reason in itself for tourists to come to Guam and spend their holiday there, regardless of whether they actually participate in marine-related activities or not. Therefore, calculating the recreational benefits involves much more than simply adding up the generated value of the diving and snorkeling industry. On the other hand, not all revenues generated by the tourist industry are marine-related. To determine the indirect economic tourist value of coral reef-related ecosystems in Guam we need to calculate the producer and consumer surplus.

Producer surplus

In calculating the producer surplus we need to multiply the cost price of marine-related tourism with the number of tourist days spent in Guam. We make several crucial assumptions to calculate the producer surplus:

Marine-related share of tourist revenues: As explained in the previous section (see Table 4.7), we assume that 28.5% of the reason tourists come to Guam is because of its marine-related attractions (such as the sea, the beach and its coral reefs). Therefore, as shown in Table 4.8, we start by discounting the gross tourist revenues accordingly.

Producers surplus: Rather than accounting for the gross revenues of marine-related tourism revenues, we need to consider only the cost price of providing these tourist services. Similar to the fishery calculations, we use the value added by the tourist industry as a proxy for the cost price. Because no information was found on the value added for the various sectors in Guam, and Hawaii is to some extent comparable to Guam's, we adopt the levels known for the Hawaiian economy (Cesar *et al.*, 2001).

Table 4.8 Average Compulsion of Spending (in US$)

Nationality	Air Fare	Hotel	Food	Other	Total
Gross expenses	392	229	185	392	1197
Marine-related factor	*28.5%*	*28.5%*	*28.5%*	*28.5%*	
Marine-related value added	112	65	53	112	341
Cost price factor	*25%*	*25%*	*25%*	*25%*	
Cost price	28	16	13	28	85

Sources: Cesar *et al.* 2001.

As shown in Table 4.8, this calculation indicates that for each tourist that arrives in Guam, the marine-related producer surplus amounts to US$85 per visitor. Table 4.4 shows how, in the last five years, an average of one million tourists visited Guam every year. This means that the marine-associated producer surplus of tourism in Guam amounts to US$85.4 million per year.

Consumer surplus

The consumer surplus of marine-related benefits of the tourist industry is defined as the payment that visitors are willing to make for their marine-related experience in Guam, in addition to the actual expenditures that they already make during their visit. The common method to measure this WTP is to apply the contingent valuation method or the travel cost method. Because the necessary financial means to conduct an elaborate tourist survey to determine the non-market value of coral reef services to foreign visitors are lacking in this study, we need to use alternative approach to estimate the consumer surplus of the marine-related tourist industry.

There is now a substantial literature on coral reef valuation. Brander *et al.* (2006) collected 160 coral reef related studies that contained economic elements. This 'flood of numbers' necessitates the application of research synthesis techniques, and in particular meta-analysis, in order to assess the results of this literature as a whole and identify the key explanatory factors that determine coral reef value. Meta-analysis can be defined as a quantitative analysis of summary indicators reported in a series of similar empirical studies. Meta-analysis extends beyond a state of the art literature review by examining the results of multiple studies in a statistical manner. Proponents of meta-analysis maintain that the valuable aspects of narrative reviews can be preserved in meta-analysis, and are in fact extended with quantitative features (Rosenthal and DiMatteo, 2001). In the case of coral reef valuation, a standardized shadow price can be analyzed, such as the dollar value per year of one km^2 of coral reef area or the willingness to pay (WTP) per coral reef visit.

The above-mentioned database developed by Brander *et al.* (2006) is used to extract values for benefit transfer in the Guam study. From the 160 coral reef-related studies present in the database, 47 studies contain CVM estimates of WTP for recreational use of coral reefs, such as diving and snorkeling. These estimates reflect the additional payment visitors are willing make for the same experience, or in some cases, with the knowledge that the additional payment is used for conservation of coral reefs. As can be seen in Figure 4.10 the majority of the WTP estimates range between $0 and $10 per person per trip. The median of the estimates is $4.48 and average of the range is $9.23 per person per trip. Knowing that high-income visitors from Japan dominate the Guam market and that the WTP per person is partly explained by household income of the visitors, we adopt the average estimate as the proxy for the consumer surplus of coral reef related recreational activities. Adopting the average number of visitors of one million per year, we estimate the consumer surplus to account for US$9.23 million per year.

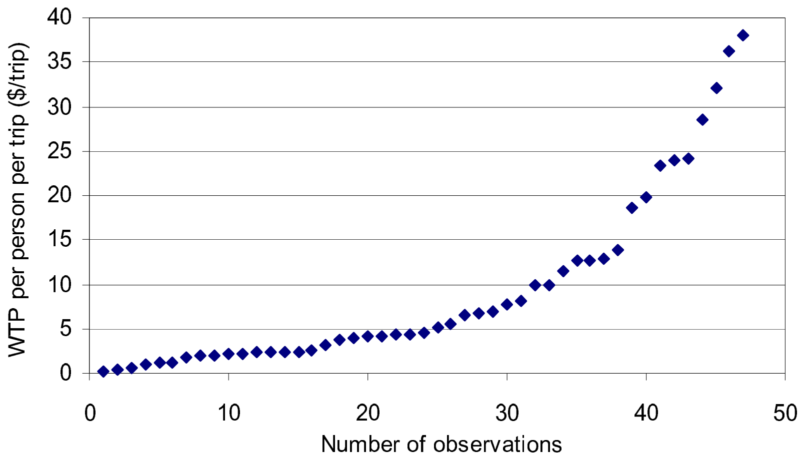

Figure 4.10 Estimations from the literature for the additional WTP for coral reef related recreational activities. (Source: Brander et al., 2006).

4.5 Diving and snorkeling

As mentioned earlier, the main types of ocean-related recreation in Guam include scuba diving, snorkeling, jet skiing, kayaking and (wind)surfing. Clearly, these activities generate substantial direct revenues to the Guam economy. Little is known about the exact extent of these activities in Guam. In this section we attempt to determine the volume and direct economic importance of the marine-related activities to Guam. Greatest emphasis in this evaluation is placed on the diving industry, because its link with coral reef ecosystems is most explicit. Moreover, within the water sports industry, the diving sector is the best documented in terms of volume and values. Therefore, we first calculate the extent of the diving activities in Guam, after which we extrapolate these findings to other water sports activities.

Importance of the dive industry

A 2001 study by the Guam Visitors Bureau identified 13 dive companies currently operating on the island. The dive companies responded with varying degrees of thoroughness to a voluntary survey designed to identify basic services offered and fees. Information provided by the companies indicated that there are 13 dive boats currently operating on the island, and 99 certified instructors. In addition to the dive companies that were identified by GVB, there is likely to be a large number of unlicensed and unregulated "fly-by-nighters" that operate out of 1-2 vans and handle small groups of tourists (speculated by DAWR, UOGML, and BSP officials).

The Pacific Association of Dive Industry estimates that over 5,000 people were certified in Guam in 2003 following the PADI "Open Water" course (John Bent, president of the Pacific ADI, personal communication). This corresponds well with the official PADI statistics (Figure 4.11). As shown in Figure 4.12, the majority of the certified divers were Japanese visitors (88%).

Certification occurs in three main areas, which are thus exposed to an extremely high number of novice divers annually. One of these areas is located in a Marine Preserve. In the wake of September 11, a favored spot within the harbor has been off-limits to most divers, so the pressure at the remaining two locations has increased.

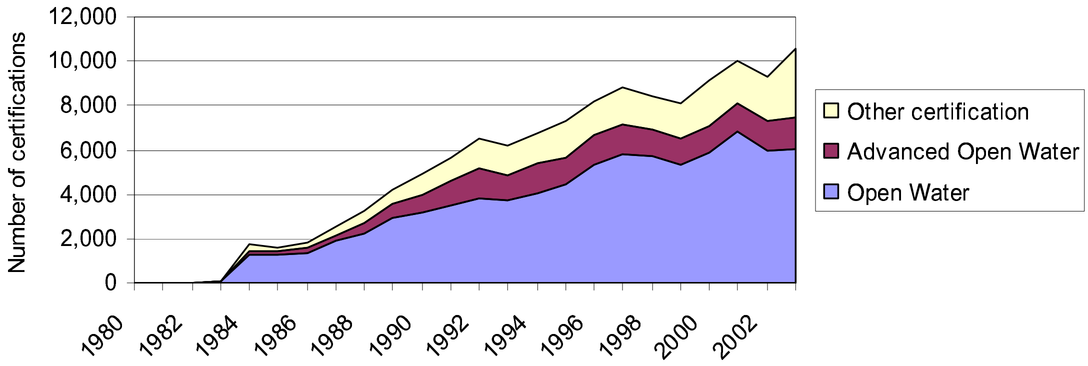

Figure 4.11 Certification of PADI divers in Guam over time (period 1980-2003)

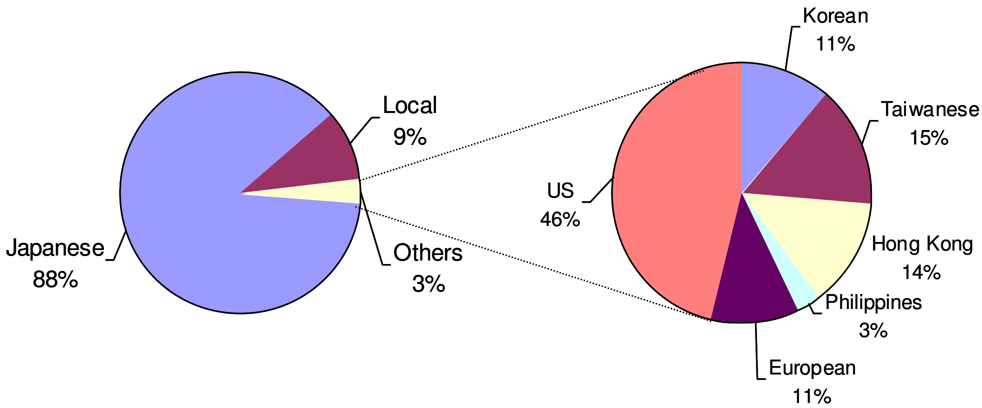

Figure 4.12 Customer composition of dive companies in Guam

Source: Wedding, Dive and Waterpark Study, Guam Visitors' Bureau, 2001

Number of divers

For the purposes of this study, it was important to determine the approximate number of dives occurring on the island every year. This number is not easy to discern, as many of the dive shops on the island consider customer information to be confidential and will not disclose the number of dives conducted per year. A second problem associated with estimating dives is the large number of "fly-by-nighters", who may not possess a valid business license, are not listed in the phone book and are nearly impossible to track.

Despite these setbacks, the number of dives occurring on the island can be estimated using two different methods. The first involves estimating the *number of air tanks* being filled per day on the island. Mr. Pete Peterson, owner of Micronesian Divers' Association (MDA is one of the largest diving companies on the island, with 32 instructors and 3 boats) estimates that 1,000 tanks per day are filled on the island. MDA has one of the 8 compressors on the island, and they alone fill 400 tanks per day. Using the estimate of 800 to 1,000 tanks per day, and assuming 320 to 340 "diveable" days per year, this would lead to a range of 256,000 to 340,000 dives per year for the island (see Table 4.9).

Table 4.9 Tank filling methods to estimate the annual number of dives per year

Estimate	Diving days	Tanks filled	Total / year
Low	320	800	256,000
Medium-Low	340	800	272,000
Medium-High	320	1,000	320,000
High	340	1,000	340,000

A second way of estimating the number of dives per year is based on the *tourism exit surveys* conducted by the GVB in 2000. These estimated the percentage of visitors (for each major nationality) that were motivated to come to Guam for scuba diving. This was done in combination with a targeted market segmentation study for Japanese visitors by the GVB (from October 2003 through September 2004). The latter study shows how, on average, 6.7% of Japanese visitors fall into the diver category. For 2002, this would equate to approximately 62,000 visitors who participate in diving during their stay (see Table 4.10).

Table 4.10 Estimation of Total Diving Visitors for 2002

Origin	Total visitors for 2002	Share of divers	Number of divers
Japan	786,867	6.7%	52,720
Korea	128,307	2%	2,566
Hong Kong	8,444	15%	1,266
Taiwan	19,500	13%	2,535
US/HI	33,233	8%	2,659
Total	976,351	6.3%	61,746

Next, we needed to capture activities of the local divers in Guam. Two dive shops on the island receive most of the local divers: Micronesian Divers' Association (MDA) and Guam Tropical Dive Station (GTDS). As cited in the Guam Visitors' Bureau "Wedding, Dive, Waterparks 2002" study, 45% of the GTDS customer base is local, while 75% of the MDA customer base is local. No other company reported more than a 3% local customer base. Mr. Pete Peterson of MDA estimated the number of locals' dives per day to be 120 on weekdays and 200 on weekends. Multiplying these two numbers by an estimated 320 "diveable" days per year leads to a range of 64,000 to 128,000 local dives per year for the island. Combining the estimated diving visitors with local divers yields a total range of approximately 190,000 to 375,000 dives per year for the island (see Table 4.11).

Table 4.11 Estimation of Total Dives per Year for Guam

Estimate	# Visitors	# Dives	Visitor Dives	Local dives	Total Dives
Low	61,746	2	123,492	64,000	187,492
Medium-Low	61,746	2	123,492	128,000	251,492
Medium-High	61,746	4	246,984	64,000	310,984
High	61,746	4	246,984	128,000	374,984

The two methods for estimating total numbers of dives per year conducted on the island yield relatively similar results. The 'tank fillings' method generates an estimate of between 256,000 and 340,000 dives per year; the 'exit survey' method yields an estimate of between 190,000 and 375,000 dives per year. On the basis of these approximations, the estimate used in this study is 300,000 dives per year (one third being local dives and two thirds being international dives).

Other marine-related activities

Besides diving, a number of other marine-related activities are important determinants of the recreational value of the marine ecosystems of Guam. Limited resources are available to quantify these activities. The tourist exit surveys gauge optional tour participation rates among the main nationalities of visitors. Scuba diving, underwater observation, and dolphin watching were some of the tour options available, and participation rates ranged from less than 10% to over 40% for some nationalities (see Table 4.12). Typically, the variation between nationalities is significant. On average, however, we could determine the number of foreign visitors that participate in dolphin watching (80,000 people), underwater observation (60,000), scuba diving (62,000), fishing (24,000), parasailing (60,000) and jet skiing (85,000).

Table 4.12 Optional Tour Participation Rates (percent)

Optional tours	Japan	Korea	Hong Kong	Taiwan	US/Hawaii	Average
Dolphin Watching	13	5	17	48	5	13
Underwater Obs.	11	0	20	19	8	10
Scuba diving	10	17	24	30	16	11
Fishing	4	1	7	8	4	4
Parasailing	11	6	17	17	5	10
Jet skiing	10	53	28	20	5	14

* Weighed average

Source: GVB 2000, Master Report

An important marine-related activity in Guam is jet skiing. Jet skis are allowed to operate in three confined areas, one of which is in shallow water. As a result, the jet skis have eroded a "halo" of bare rock within the back reef area (see Figure 4.13) and this area is not used for swimming, kayaking, paddling, diving, or other types of water recreation.

Figure 4.13 The"halo" of bare rock in the shallow reef flat caused by jet skis

In addition to the recreational activities of off-island visitors, many local residents enjoy the benefits of ocean and water recreation. Guam has a small, but growing, paddling community that frequents the protected areas inside the reef. Many paddlers can't swim, and wouldn't participate if the paddling occurred outside the reef. As explained earlier, local residents also visit the beaches for family gatherings that usually involve wading or playing in the shallow water immediately adjacent to the beach. Picnic shelter reservations data from the Department of Parks and Recreation show that annually, large numbers of individuals book to use beachside areas.

Monetary valuation of marine related activities

Similar to the tourist value, the diving and snorkeling value in Guam is defined as the sum of the producer and consumer surplus. The marine-related consumer surplus of foreign visitors has already been determined in the previous section, and is therefore not separately estimated in the diving and snorkeling section. The consumer surplus of local residents is not captured in this estimate. As was shown in Table 4.11, the number of dives by local residents is estimated to lie within a range of 64,000 and 128,000 dives, with an average of 100,000 dives per year. On the basis of the previously presented meta-analysis (see Figure 4.10), we assume a consumer surplus for local activities of US$4.48 per activity. We adopt the lower median estimate instead of the higher average estimate because the household income in Guam is significantly lower than the average tourists that visits Guam (i.e. note that the WTP estimate is predominantly determined by income levels of the respondent). As a result, the local consumer surplus amounts to US$0.448 million (i.e. 100,000 dives multiplied by a WTP of US$4.48 per dive).

The producer surplus is mainly dependent on the cost price of coral-reef related activities, such as diving and snorkeling. In turn, the cost price of these activities is best reflected by the actual prices paid for in the market. As shown in Table 4.13, prices for a two-tank dive range from US$35 to $100 for local divers and between US$80 and $110 for foreign divers. The most expensive package a diver can purchase on Guam is the 'Open Water' certification, costing between US$300 and $500 for foreign divers.

Table 4.13 Price list of various dive-related services (in US$)

Service	Average	Minimum	Maximum*
2-tank dive (tourist)	96	80	110
2-tank dive (local)	61	35	100
Intro Dive (tourist)	78	70	90
Intro Dive (local)	62	25	85
Open Water Cert (tourist)	393	300	500
Open Water Cert (local)	296	149	450
Adv. Open Cert (tourist)	336	200	450
Adv. Open Cert (local)	201	100	350
Dolphin Watch (tourist)	68	40	120
Dolphin Watch (local)	47	25	69

Source: Wedding, Dive and Waterpark Study, Guam Visitors' Bureau, 2001.

Note: The maximum values were registered at top-class hotels and 5-star resorts.

To determine the producer surplus of water sports in Guam, we applied a similar accounting method to that used to determine the marine-associated economic value of tourism (see previous section). Although diving is the most important water sport in Guam, other activities (such as dolphin watching, underwater observation and fishing) are also relevant when determining the economic value of Guam's marine ecosystems. Parasailing and jet skiing are excluded from the economic value because these activities are not truly dependent on healthy marine reef ecosystems: these activities can take place without the presence of healthy reefs.

As with the calculation of the tourist value, we transform the price of each water sport into an economic value by applying corrections on the basis of a cost price factor of 0.4 (see Table 4.14). Due to a lack of information, we assume the price of the other water sports to be equal to the price of a one-tank dive (i.e. the price of a two-tank dive divided by two). The number of trips per active visitor is assumed to be one for the non-dive activities, and 3.23 for foreign divers. For local scuba diving, we do not know the number of divers but we do know the number of dives, which is sufficient to determine the economic value of local diving. By multiplying the value added with the number of trips for each activity, the total economic value of these recreational activities is determined. The last row of Table 4.14 shows how foreign diving generates most of the economic value of recreational activities. Dolphin watching comes second place. The total (market) value of these marine-related water sports amounts to US$8.24 million.

Table 4.14 Direct economic value of marine ecosystem associated water sport activities in Guam (in US$)

Nationality	Diving – Local	Diving – Visitors	Dolphin watching	Underwater observation	Fishing
Gross expenses	$30	$50	$50	$40	$50
Cost price factor	40%	40%	40%	40%	40%
Cost price	$12	$20	$20	$20	$20
Number of people	n.a.	62,000	80,000	60,000	24,000
Number of trips per person	n.a.	3.23	1	1	1
Number of trips	100,000	200,000	80,000	60,000	24,000
Economic (market) value	$1,200,000	$4,000,000	$1,600,000	$960,000	$480,000

4.6 Biodiversity

Guam's proximity to the Indo-Pacific centre of marine biodiversity has led to the presence of more numerous species of stony corals, species of fish, and species of invertebrates (Veron, 2000). While generally more diverse than other Pacific or Atlantic regions, Guam does not possess the range of diversity seen in other Micronesian islands such as Palau or the Federated States of Micronesia (FSM).

Guam has experienced a decline in the health and diversity of its coral reefs over the past four decades. While few long-term monitoring studies exist for the island, the trend has been observed by the fishing community and research community alike. Several isolated studies have documented the decline. In 1971, Randall found approximately 50% cover of live corals on Guam's fore reef slopes. A similar study in 1997 by Birkeland found less than 25% live coral cover in most areas, with only a few areas having 50% live coral cover. An even more alarming trend is the decline in recruitment rates found during three successive studies by Birkeland. In 1979, Birkeland *et al.* (1982) observed 0.53 coral recruits per plexiglass fouling panel. The recruitment rate found during a similar experiment in 1989 was 99.3% lower than that of the 1979 study (0.004 recruits per plate); the rate found during a similar experiment in 1997 was 98.7% lower than that of the 1979 study (0.009 recruits per plate). This drastic decline does not bode well for the future of Guam's coral reefs.

A concerned Guam community supported the establishment of 5 marine preserves in 1997, covering approximately 11% of the island's coastline. Guam remains the only US territory to have met or exceeded the nationwide goal of setting aside 10% of reef areas for protection (NOAA, 2005).

Despite the decline in reef health, the biodiversity of Guam's coral reefs still attracts substantial research funds. As shown in Table 4.15, in the past four years, more than US$7.5 million have been invested in further research and education. Because this amount shows some increase over time, we will assume that the market component of the research or biodiversity value of coral reef ecosystems is around US$2 million per year. Due to the limited means to estimate the non-market component of biodiversity by means of a survey and the lack of non-market estimates of biodiversity in the literature, this aspect of the total economic value is not taken into account in this study.

Table 4.15 Biodiversity and research funds linked to marine-resources in Guam for the period 2000 to 2004

Year	Research fund
2000	757,147
2001	1,061,966
2002	2,175,705
2003	1,774,222
2004	1,750,239

4.7 Amenity value

Houses and hotels in the vicinity of a healthy marine system are generally more valuable than comparable properties further from the coast. The view of a clean beach and a healthy coral reef is perceived to be a benefit to those who can enjoy it every day. Therefore, beachfront houses along a beautiful coast with clean beaches and healthy coral reefs generally sell for significantly higher prices. Likewise, condos and hotel rooms adjacent to healthy marine systems generally operate at higher room and occupancy rates.

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 in the vicinity of healthy marine systems can be measured. Combining this with the number of the residential houses leads to a positive amenity value attributable to a healthy coral reef.

Two studies are particularly helpful in estimating the marine-related real-estate value of properties in Guam. Wertheim *et al.* (1992) quantify the different relationships between characteristics that affect the value of beach property in the US. Edwards and Gable (1996) estimate the relationship between beach recreation and property value. Among others, they show that distance to the beach and the quality of the marine ecosystems have a strong impact on the value of properties.

No detailed data are available on the extent to which healthy coral reefs affect the house prices on Guam. Therefore, we have to find alternative ways of estimating this value. We did manage to retrieve a database containing background information on 828 house sales that took place during the period 2000-2004. The average sales price reported in the dataset is US$135,000 per house. The parameters provided in the database include the address, listed price (US$), selling price (US$), surface area (square foot), date of sale, and the number of bedrooms and bathrooms. With these data we were able to conduct a regression analysis through which we determined the effect of location on house prices. Obviously, this is not the same as the amenity value of coral reefs, but it does provide an indication of the maximum magnitude of the effect.

The multiple regression analysis (in which several potential determinants of the sales prices of houses in Guam are tested, using a simple OLS), provided the following result (the numbers between brackets report the t-values):

Price	US$69,509	- 17*distance	+ 101*surface area	+ 4,053*bathrooms	- 17,818*bedrooms
	(7,652)	(-5.012)	(25.408)	(-6.953)	(2.167)

The explanatory power of the independent variables was substantial (i.e. adjusted R^2 of 0.562). All tested variables proved to be significant. The results broadly met with our expectations: the further away the property is located from the coast, the lower the price. In fact, with every additional kilometer away from the coast, the value of the house declines by US$17,000. Similarly, the average surface area price is around US$100 per square foot. Each extra bathroom entails an increase in value of around US$4000. The only result that was difficult to interpret was the fact that the number of bedrooms is negatively related to the house price. Given that this variable has the lowest level of significance, we assume that this outcome results from poor data quality, and is therefore incorrect.

If we extrapolate the above results (assuming that the amenity effect is neutralized after 1.5 kilometers) we can calculate the overall amenity value of coastal attributes. Table 4.16 shows how many buildings are located in the various zones. The gross real estate value of the buildings in Guam amounts to US$5.3 billion. The surplus amenity value declines in a linear manner with distance from the coastline. The last column in Table 4.16 shows the aggregated amenity value of US$321 million, which is 6% of the gross real estate value. Assuming a discount rate of 5%, which is common in environmental economic studies (Pearce and Ulph, 1995) and a time horizon of 100 years, this suggests an annual value of US$15.4 million.

Table 4.16 Calculation of marine-related amenity value

Zone	Number of buildings (*#*)	Gross value (*million US$*)	Surplus value (*US$/house*)	Gross surplus value (*million US$*)
0-100m from coast	1,179	159	25,500	30
100-250m from coast	1,978	267	22,525	45
250m-1000m from coast	9,813	1,325	14,875	146
Beyond 1000m	26,624	3,594	3,754	100
Total		5,345		321

It should be realized, however, that the value of US$15.4 million is an upper bound estimate as it refers to the total value of all marine-related amenities, of which coral reefs are only one element. With the currently available information it is impossible to determine the extent to which the value is specifically dependent on the presence of healthy coral reefs. Coral reefs provide a direct role (i.e. the pleasure of the proximity of a reef) as well as a indirect role (i.e. as a provider of sand grains for white beaches) to the amenity value. Therefore the lower-bound value of the amenity value of coral reefs is by definition more than zero. We arbitrarily assume that the lower boundary value of coral reefs is 25% of the total amenity value. This implies an average coral reef related amenity value of US$9.6 million, with a lower- and upper-bound estimate of US$3.85 million and US$15.4 million, respectively.

4.8 Coastal protection

The role of reefs in coastal protection

Risks of flooding, inundation, and coastal erosion depend on both physical properties of a given island (such as elevation, rock and soil-type, and location) and on biological properties (such as the existence of buffering habitats, like coral reefs or mangroves). Reefs are natural breakwaters; they absorb much of the incoming wave energy and help protect the shoreline from erosion. For example, in Nicaragua, measurements showed that up to 77% of the force of waves is eliminated by discontinuous coral reefs (UN Atlas of the Ocean, 2000). As a result, without the wave buffering and sand production roles of coral reefs, rates of coastal erosion and beach loss (and associated economic damage) would be significantly higher.

Recent studies in Guam provide quantitative analyses of how the coastal profile influences the dissipation of wave energy. Figure 4.14 shows schematic coastline profiles of Guam and Hawaii. In areas where broad reef flats are part of the coast, wave energy is spread over a larger area; in locations where steep, rocky coastlines prevail, wave energy tends to be concentrated on a smaller area. In many places where storm damage required rebuilding of infrastructure (such as after Hurricane Iwa in 1982) an examination of geologic and storm-susceptibility maps would have suggested that a reasonable construction ‘setback’ would have reduced insured losses (Richmond, 1994).

Manmade structures cannot simply replace the buffer function of coral reefs, because these structures themselves may have negative effects (such as increased rates of beach erosion). For example, preliminary examination of a report on shoreline changes from

1949 to 1989 in Hawaii suggests that i) 62% of the sandy shoreline studied on Maui is eroding at an average rate of 1.25 ft/yr (Hwang and Fletcher, 1992), and ii) as much as 30% of Maui's shoreline has experienced beach loss or significant narrowing (Makai Ocean Engineering, Inc. and Sea Engineering, Inc., 1991). Based on field and photographic observations, nearly all of this beach degradation is in front of or adjacent to shoreline armoring such as seawalls and revetments.

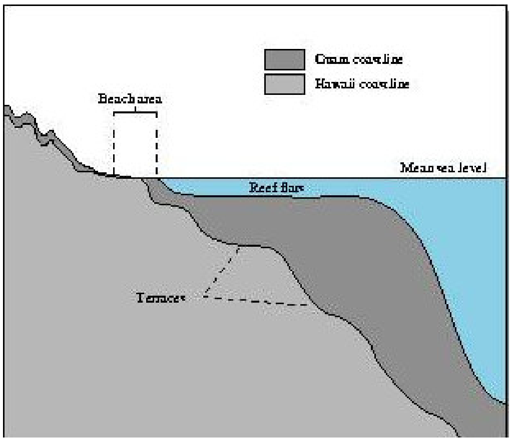

Figure 4.14 Coastline profile of Guam and Hawaii

Source: USGS, 2004.

Storms and typhoons in Guam

The coastal protection function of coral reefs in Guam is very important because the island is located in the "typhoon belt" and is threatened by the passage of tropical cyclones all year round. During the period 1945-1994, there were 183 tropical storms and typhoons, which passed within 180 nmi (nautical mile) of Guam. As shown in Figure 4.15, most tropical storms in Guam come from the east (around 80%). The remaining 20% of storms come from the west (Richmond and Davis, 2002).

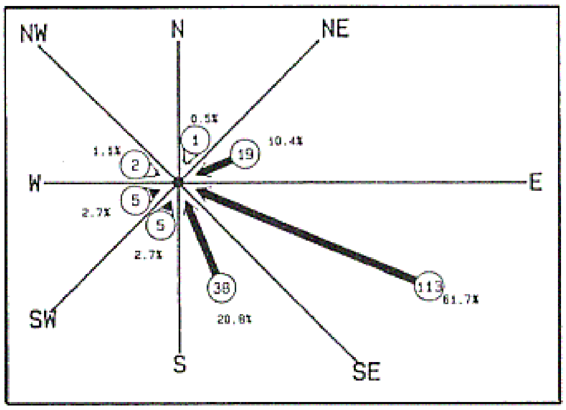

Figure 4.15 Storm directions in Guam (circles contain number of storms in the period 1945-1994)

Figure 4.16 shows the chronology of all typhoons and tropical storms that passed over and near Guam during a 50-year period (1945-1994). The frequency is 3.5 tropical storms per year. Richmond and Davis (2002) report that Guam experiences one substantial tropical storm every year. What is alarming is that, on the one hand, storms are tending to become more frequent and intensive, while on the other hand, the potential for infrastructure and private properties to be damaged is growing due to an increase in population growth.

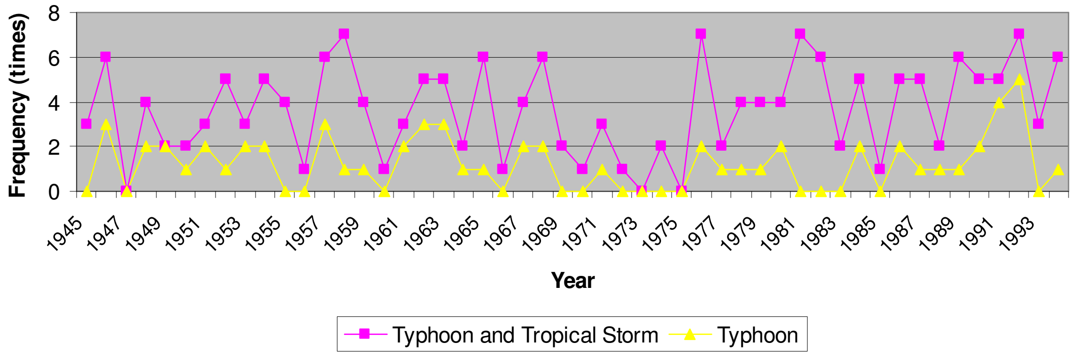

Figure 4.16 Chronology of tropical storms and typhoons in Guam 1945-1994 (Source: NRL, 2005; Brown and Brand, 1975)

The height of waves and storm surges created by tropical storms with and without protection provided by coral reefs in Guam are shown in Figure 4.17. The maps show the wave heights (i.e. in meters) during storms in a situation with reefs (i.e. wave height varies between 2 and 6 meters) and without reefs (i.e. wave height varies between 4 and 12 meters). In a situation 'with coral reefs' (see (a) and (b)), waves are expected to be two times lower than in a situation 'without coral reefs' (see (c) and (d)) (UN Atlas of the Ocean, 2000).

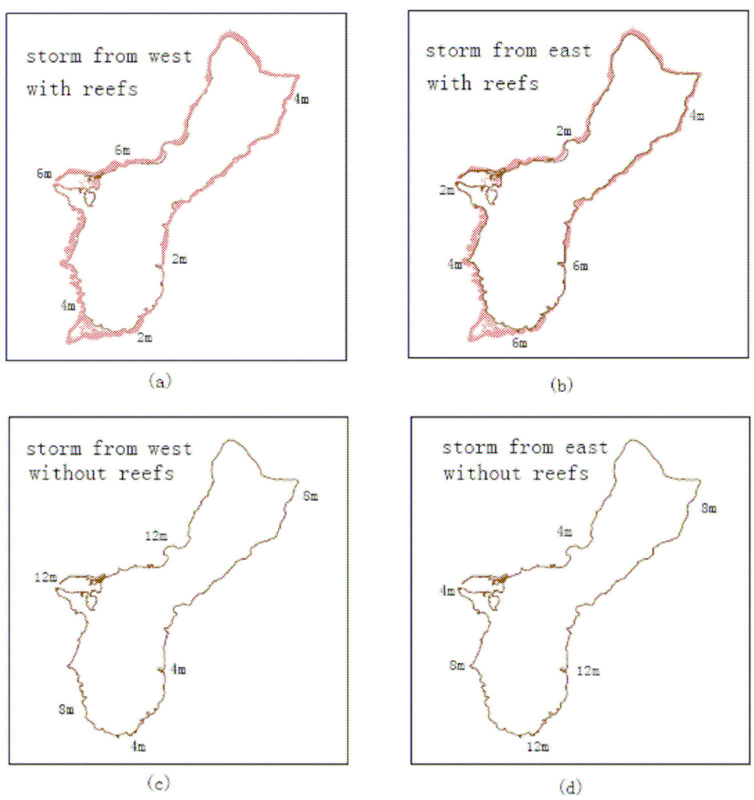

Figure 4.17 Potential height of waves and storm surges with and without coral reefs (source: UN Atlas of the Ocean, 2000).

The hidden value of coastal protection

The actual value of coral reefs in terms of protecting the coastal zone is not visible unless the reefs degrade and the storm surges become more destructive, causing more damage than before. Therefore, we can only calculate this 'hidden' economic value of coastal protection (i.e. avoided damage) by comparing hypothetical situations in which the intensity of storms (assessed by means of wave height) and the presence of healthy coral reefs varies.

The amount of damage depends on the density of buildings and infrastructure. The higher the density of potentially vulnerable buildings, the greater the coastal protection value of coral reefs. Through GIS, the potential flooding zones created by storms coming from both the west and the east have been identified for a situation with and without reefs. Next, the number of buildings in these flooding zones was counted and valued accordingly (see Table 4.17).

Table 4.17 Number of buildings at risk in one year for Western and Eastern storms in a situation with and without coral reefs (in US$)

Scenario	West	East
Potentially destroyed buildings 'with reefs' *(# building)*	667	395
Additional potentially destroyed buildings 'without reefs' *(# building)*	1459	502
Value of at risk buildings 'with reefs' *(million US$)*	90	53
Additional potentially destroyed buildings 'without reefs' *(million US$)*	197	68
Ratio of property value loss of affected building	5%	5%
Value of at risk buildings 'with reefs' *(million US$)*	4.5	3.4
Additional potentially destroyed buildings 'without reefs' *(million US$)*	9.8	2.7

Of course, typhoons do not only cause damage through flooding. In fact, substantial damage is done through wind, rain and landslides. Also, affected houses are not always completely damaged but may need significant repair after floods hit the property. Therefore, when calculating the coastal protection value of coral reefs in Guam, we need to make assumptions about the average damage done by storms. We calculated that the average value of a piece of property is US$135,000; we go on to assume that an affected house will be damaged in the magnitude of 5% of the property. Combining this information with our knowledge of storm direction (a division of 80/20 coming from west and east), we could determine the avoided damage attributable to healthy coral reefs. With healthy reefs, the average damage each year amounts to US$4.3 million. Without the presence of coral reefs, this damage would increase to a level of US$12.7 million per year. Therefore, the coastal protection value of coral reefs in Guam is determined to be US$8.4 million per annum.

4.9 Total economic value

After calculating the economic values of the individual coral reef associated goods and services, we aggregate these values to determine the TEV (see Table 4.18). The TEV of US$127 million represents the economic importance, in absolute terms, of market and non-market values of coral reefs in Guam. The indirect importance for the tourist industry account for 74% of the TEV. Of second and third importance are the amenity

(8%), coastal protection (i.e. 7%) and watersports (i.e. 7%) segments. Typically, with only half a percent, the only consumptive good (i.e. market value of the fishery sector) is almost negligible compared to the other non-consumptive goods and services. This is an additional motive to promote more sustainable fishery policies, since a further decline of the fish stock will also negatively affect more valuable goods such as diving and snorkeling. All in all, coral reefs and its surrounding marine environment represent a significant asset to Guam's economy and culture. This importance is not entirely reflected by the funds that are made available by the Guam government to manage the reefs.

Table 4.18 Total Economic Value of coral reefs in Guam

Type of reef-related value	Market value (*million US$/year*)	Non-market value (*million US$/year*)	Economic value (*million US$/year*)
Tourism	85.40	9.23	94.63
Diving and snorkeling	8.24	0.45	8.69
Fishery	0.54	3.42	3.964
Amenity	n.a.	9.60	9.60
Coastal protection	n.a.	8.40	8.40
Biodiversity	2.00	n.a.	2.00
Total Economic Value	96.18	31.10	127.28

We acknowledge that there are many conceptual and empirical problems inherent in producing the estimates of the TEV of the coral reefs of Guam. For one, we were only able to assess part of the cultural, biodiversity, and non-use values. Another example is that different valuation techniques have been used simultaneously to estimate the TEV. Although we have carefully prevented overlapping values, such an approach is still rather uncommon in valuation studies. Studies that have attempted similar exercises have been criticized in the scientific community for its disregard for the significant uncertainties in the data and the underlying assumptions (see, for example, Constanza et al. 1997). We stress, however, that given the significant uncertainties involved, we may never have a very precise estimate of the TEV of the coral reefs of Guam. Nevertheless, even the crude initial estimate we have been able to assemble is a useful starting point for further research.

To demonstrate the level of uncertainty of the initial estimate, we provide an overview of the minimum and maximum estimates that have been determined for various individual value categories. The range for tourism benefits from US$64 to US$120 million is determined by the extent to which the income of the tourist industry can be attributed to marine-related goods and services. The range for diving and snorkeling between $5 and US$10 million is based on different levels of participants in watersports activities. The range in fishery benefits from US$1.2 to US$6.6 million is mainly based on scenario assumption in the choice experiment. The range in the amenity values is determined by the extent to which the amenity surplus is attributable to coral reefs as opposed to marine-related amenities in general. The limited amount of data underlying the calculations for coastal protection and biodiversity values did not allow for variations in these two value categories. Ultimately, the total economic value of coral reefs in Guam varies between US$85 million and US$164 million, with a core estimate of US$127 million per year.

Table 4.19 Estimate ranges of the total economic value (million US$/year)

	Tourism	Diving & snorkelling	Fishery	Amenity	Costal protection	Biodiversity	Total
Minimum	63.81	5.37	1.20	3.85	8.40	2.00	84.64
Maximum	120.40	10.75	6.59	15.40	8.40	2.00	163.54
Core estimate	94.63	8.69	3.96	9.60	8.40	2.00	127.28

5. GIS and economic valuation

5.1 Introduction

The complex real world interactions between the economy and the environment form both the focus of and main barrier to applied research within the field of environmental economics. However, geographical information systems (GIS) allow economists to tackle such complexity head on by directly incorporating diverse data sets into applied research rather than resorting to simplifying and making (often unrealistic) assumptions (Bateman *et al.* 2004). GIS is particularly useful in bringing together spatially relevant economic and environmental data. This premise holds for our economic analysis of coral reefs in Guam.

The spatial dimension of interactions between the economy and coral reef ecosystems are relevant at various levels, including: (1) threats (e.g. the distance from storm water runoff channel to the reef, locations most prone to typhoon damage, areas of coastal hardening, sites with high fishing pressure, jet-ski areas); (2) benefits (such as the travel time/distance of potential visitors, spill-over distance of juvenile fish moving between MPAs and fishing grounds, distribution of real estate along the coastline, etc.); and (3) distributional aspects (e.g. where the winners and losers of specific management interventions are situated).

Although there have been many examples of the application of GIS in environmental economics, the use of GIS in the conservation/management of coral reefs is rare. One of the few early applications of GIS in this context is provided by Bryant *et al.* (1998). The infrequent use of this type of tool is somewhat surprising because, for example, there can be significant spatial variation in reef values within a region which can only be made explicit by the use of GIS. A recent study in American Samoa showed that reef values in some areas were up to 130 times the territory average (Spurgeon and Roxburgh, 2004). Major over- or underestimation can occur if values are extended (without adjustments) to another area of reef or are extrapolated across whole regions. More research is needed on factors affecting the spatial distribution of values and the magnitude of variation between benefits (e.g. through meta analyses at the regional level), as well as an examination of the potential for map-based tools (Roxburgh and Spurgeon, 2005).

In this study, we applied GIS techniques to spatial economic valuation of coral reefs in Guam. We looked in detail at issues such as real estate values, recreational and fisheries benefits. To improve our understanding of the spatial variation in the economic value of coral reefs, we created overlays of coral reef maps, population maps, tourist-use maps, fishery maps, and real-estate maps, and analyzed the relationships between these. The main goal of applying GIS was to demonstrate that coral reefs have different economic values at different locations. Combining this knowledge with the fact that different human-induced threats occur at different locations, we can identify those coral reefs that should be prioritized when taking management actions.

Various data sources were used in this endeavor. Firstly, the recent shallow water benthic habitat maps for Guam (NOAA, 2005) data was used (see Figure 1.1). Further data were available from the ReefBase Online GIS, which enabled us to display coral reef related data and information on interactive maps. Also, maps were used from ESRI, which has various datasets based on the United States Geological Survey. Moreover, many GIS overlays of Guam were retrieved from various local and federal government agencies.

Economic values associated with coral reefs in Guam were allocated spatially across the reefs with the help of GIS tools; subsequently all the maps were overlapped to get the final thematic map of the economic value distribution. After comparing this with a map of anthropogenic threats, the priority coral reefs are revealed.

The general methodology followed three distinct steps. Firstly, we allocated economic values, which were calculated in the previous chapters (see Table 5.1), to coral reefs in terms of fisheries, tourism, coastal protection, amenity and biodiversity. Secondly, we overlaid these individual value maps to produce the thematic map in which the distribution of the total economic value of coral reefs can be seen. This allowed for the ranking of coral reefs based on their allocated economic value. Thirdly, we compared the distribution of total economic value with the literature on anthropogenic threats to coral reefs in order to determine which coral reefs should receive priority protection. In other words, the aim was to work out which coral reefs had a high economic value *and* faced serious threats. The method is explained in more detail in the coming sections, in which each individual value map is determined.

Table 5.1 Coral reef related valuation in Guam

Type of reef-related value	Economic value (million US$/year)
Tourism	94.63
Diving and snorkeling	8.69
Fishery	3.96
Amenity	4.8 (Parcels 1 related) 3.0 (Parcels 2 related) 1.8 (Parcels 3 related)
Coastal protection	6.1 (Tropical storm from west) 2.3 (Tropical storm from east)
Biodiversity	2

5.2 Tourism

The recreational and tourism sites in Guam influencing the coral reef economic values include diving and snorkeling spots, beaches, parks and hotels. This section focuses solely on beaches, parks and hotels. In line with the economic valuation procedure, diving and snorkeling spots are discussed in the next section. As for general tourism, coral reef categorization is mainly based on beaches, parks and hotels, with the premise that coral reefs closer to recreational sites are more valuable for tourism.

Physical quantification

Although reefs play an important role in the tourism industry, their importance in tourism is not constant in space. To capture this spatial variability, two principles are followed. First, coral reefs closer to tourist locations are responsible for generating more income from tourism. As shown in Figure 5.1(a), coral reefs in red are more valuable than coral reefs in blue because of its proximity to the tourist site. Likewise, coral reefs in blue are more valuable than coral reefs in yellow. Second, coral reefs related to more tourism sites are more important. The example in Figure 5.1(b) simulates a situation in which there are two tourist sites close to each other. Coral reefs in blue are within 500m from both tourist sites, implying they are linked to two tourist sites. In contrast, the coral reefs in yellow are linked to only one tourist site. Therefore, coral reefs in blue are more valuable than those in yellow.

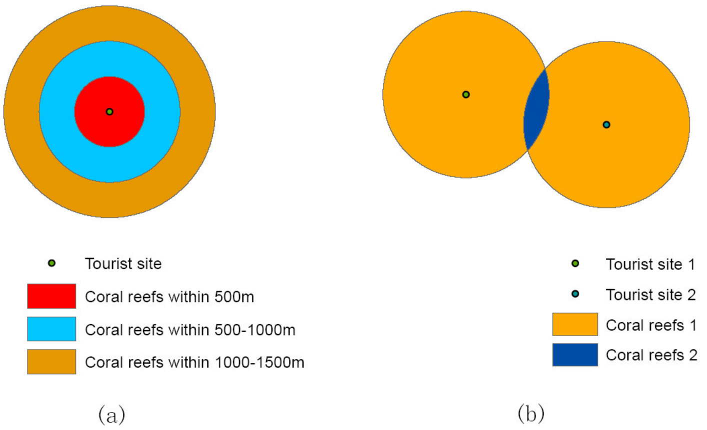

Figure 5.1 Two principles used in the distribution of tourism value of coral reefs

Following these two simple principles, several steps are taken to arrive at the economic value of coral reefs in relation to tourism in Guam. Firstly, coral reefs were classified into four categories (i.e. High, Medium, Low and Zero tourism value) according to their distance from these recreational sites. Coral reefs within 500 meters of recreational sites are considered to have a high tourism value, between 500 meters and 1000 meters a medium tourism value, and between 1000 meters and 1500 meters a low tourism value. Reefs beyond 1500 meters of recreational sites are considered to have no tourism value.

Next, we further divided coral reefs with high, medium and low tourism values into more detailed sub-categories using GIS software. In these sub-categories, coral reefs associated with all three types of recreational site have a high value. Those associated with either two of these three types of recreational site have a medium value, while those associated with one type of recreational site are seen as low value reefs.

- *Coral reefs 0-500m (3 types)*: Coral reefs within 500m of recreational sites and associated with all three types of recreational site
- *Coral reefs 0-500m (2 types):* Coral reefs within 500m of recreational sites and associated with either two out of three types of recreational site
- *Coral reefs 0-500m (1 type):* Coral reefs within 500m of recreational sites and associated with one out of three types of recreational site
- *Coral reefs 500-1000m (3 types):* Coral reefs within 500-1000m of recreational sites and associated with all three types of recreational site
- *Coral reefs 500-1000m (2 types):* Coral reefs within 500-1000m of recreational sites and associated with either two out of three types of recreational site
- *Coral reefs 500-1000m (1 type):* Coral reefs within 500-1000m of recreational sites and associated with one out of three types of recreational site

- *Coral reefs 1000-1500m (3 types):* Coral reefs within 1000-1500m of recreational sites and associated with all three types of recreational site
- *Coral reefs 1000-1500m (2 types):* Coral reefs within 1000-1500m of recreational sites and associated with either two out of three types of recreational site
- *Coral reefs 1000-1500m (1 type):* Coral reefs within 1000-1500m of recreational sites and associated with one out of three types of recreational site
- *Coral reefs beyond 1500m:* Coral reefs beyond 1500m of any recreational site

These various categories are presented in Figure 5.2. It is clear where the reefs, which enjoy the highest tourism interest, are located.

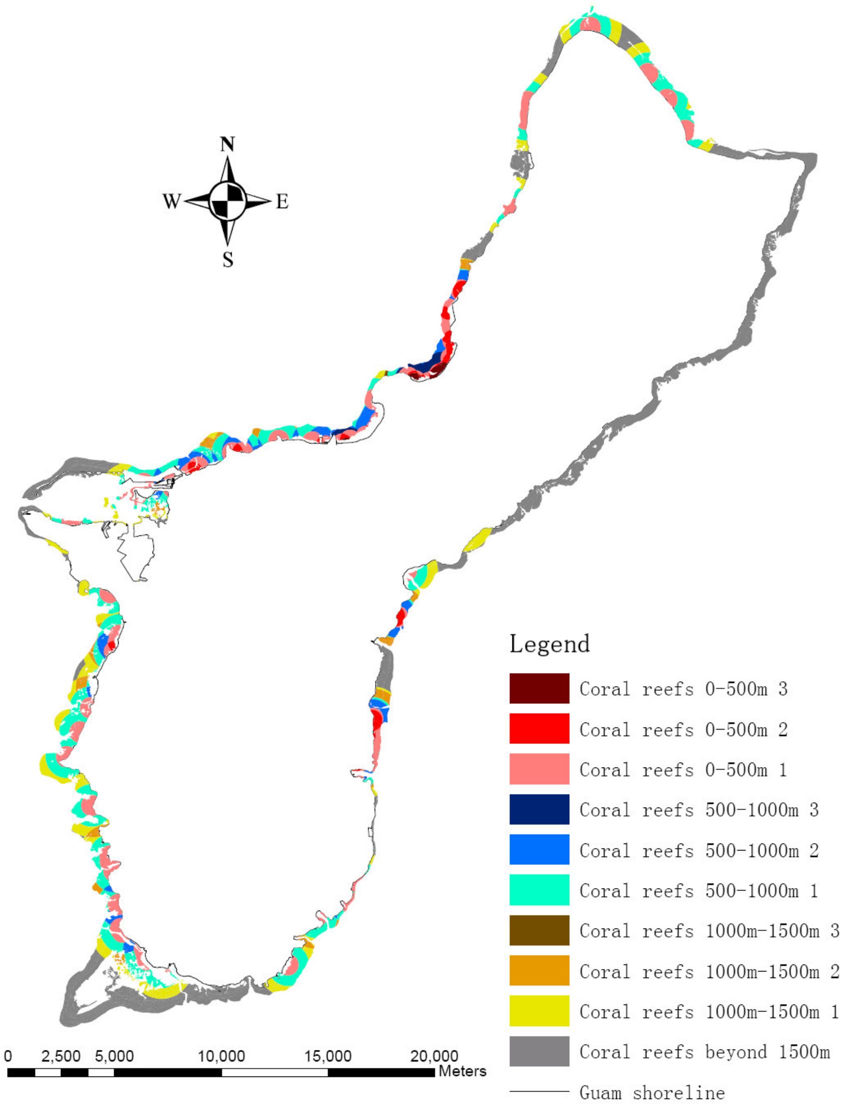

Figure 5.2 Coral-reef based tourism in Guam

Final categories and weights can be seen in Table 5.2 below. The area of each category also needed to be taken into account. The method is similar to the one used in the fishery component, with the spatial distribution of tourism values being based on a weighted score. Weights of 9/13th, 3/13th and 1/13th were applied for the proximity zones 0-500 meters, 500-1000 meters and 1000-1500 meters, respectively. Sites with three, two and one functions received 45%, 30% and 25%, respectively. The overall weights resulting from this exercise are shown in the last column of Table 5.2.

Table 5.2 Weights and scores of the various categories of tourist-related reefs

Category	Weight	Sub-category	Weight	Overall weight
High (reefs within 0-500m of recreational sites)	9	High	45%	4.05
		Medium	30%	2.70
		Low	25%	2.25
Medium (reefs within 500-1000m of recreational sites)	3	High	45%	1.35
		Medium	30%	0.90
		Low	25%	0.75
Low (reefs within 1000-1500m of recreational sites)	1	High	45%	0.45
		Medium	30%	0.30
		Low	25%	0.25
Zero (reefs beyond 1500m of recreational sites)	0	None	0%	0.00

Monetary valuation

On the basis of the above information, the total value of coral-reef related tourism of US$94.63 million per year can be allocated spatially. Table 5.3, shows the method followed to generate an economic value per unit area. Firstly, a final score for each (sub)category was determined by multiplying the overall weight from Table 5.2 by the actual area of each (sub)category. Secondly, this final score was used as the key to allocate the coral reef tourist value across the (sub)categories. Finally, this value was divided by the area of each (sub)category to arrive at a tourist value per unit area.

Table 5.3 Coral reef tourism model used in Guam

Category	Sub-category	Overall weight*	Area (km^2)	Score	Tourism value (US$)	Value per unit area ($US\$.km^{-2}.year^{-1}$)
High (reefs 0-500m from sites)	High 3	4.05	0.33	1.34	1,780,708	5,382,594
	Medium 2	2.7	4.09	11.04	14,670,906	3,588,396
	Low 1	2.25	17.38	39.10	51,959,458	2,990,330
Medium (reefs 500-1000m from sites)	High 3	1.35	0.88	1.19	1,581,375	1,794,198
	Medium 2	0.9	6.34	5.71	7,587,941	1,196,132
	Low 1	0.75	13.69	10.27	13,647,663	996,777
Low (reefs 1000-1500m sites)	High 3	0.45	0.44	0.20	265,777	598,067
	Medium 2	0.3	2.71	0.81	1,076,398	398,711
	Low 1	0.25	6.18	1.55	2,059,774	332,259
Total	--	--	71.66	71.20	94,630,000	--

After re-categorizing coral reefs according to the corresponding value per unit area, a map was created which reflected the spatial variation of the tourism value (see Figure 5.3).

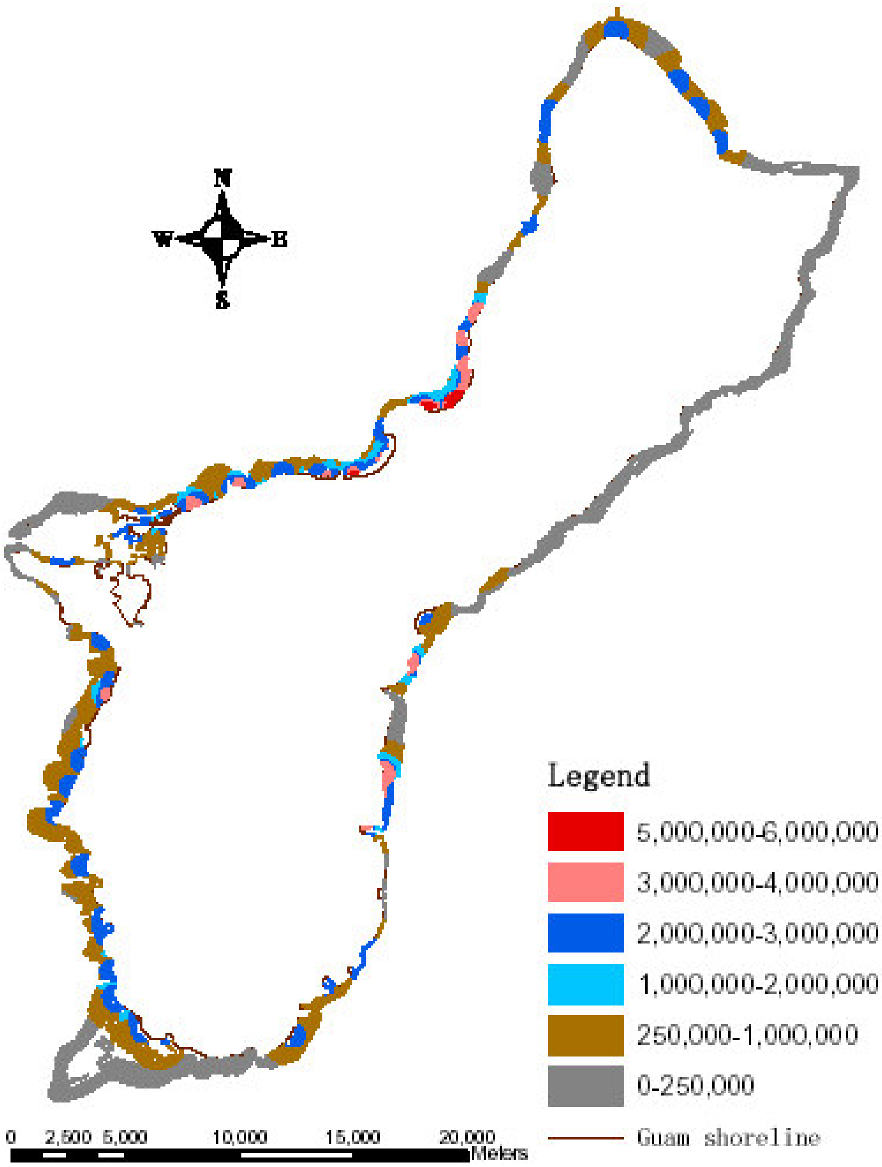

Figure 5.3 Coral reef tourism value distribution in Guam (in US$.km-2.year-1)

5.3 Diving and snorkeling

Diving and snorkeling are discussed separately from other tourism values because these activities are more directly related to coral reefs. Every year many tourists visit Guam and Saipan just for diving and snorkeling.

Physical quantification

To make the diving and snorkeling value spatially explicit, an alternative method was required. Firstly, diving and snorkeling spots were divided into three categories according to their popularity (i.e. most popular, popular and not popular spots). We considered each "popularity" category as one layer and then focused on each layer, in turn. The three levels in this category were determined on the basis of information supplied by local experts, such as dive school owners and keen divers (see Figure 5.4).

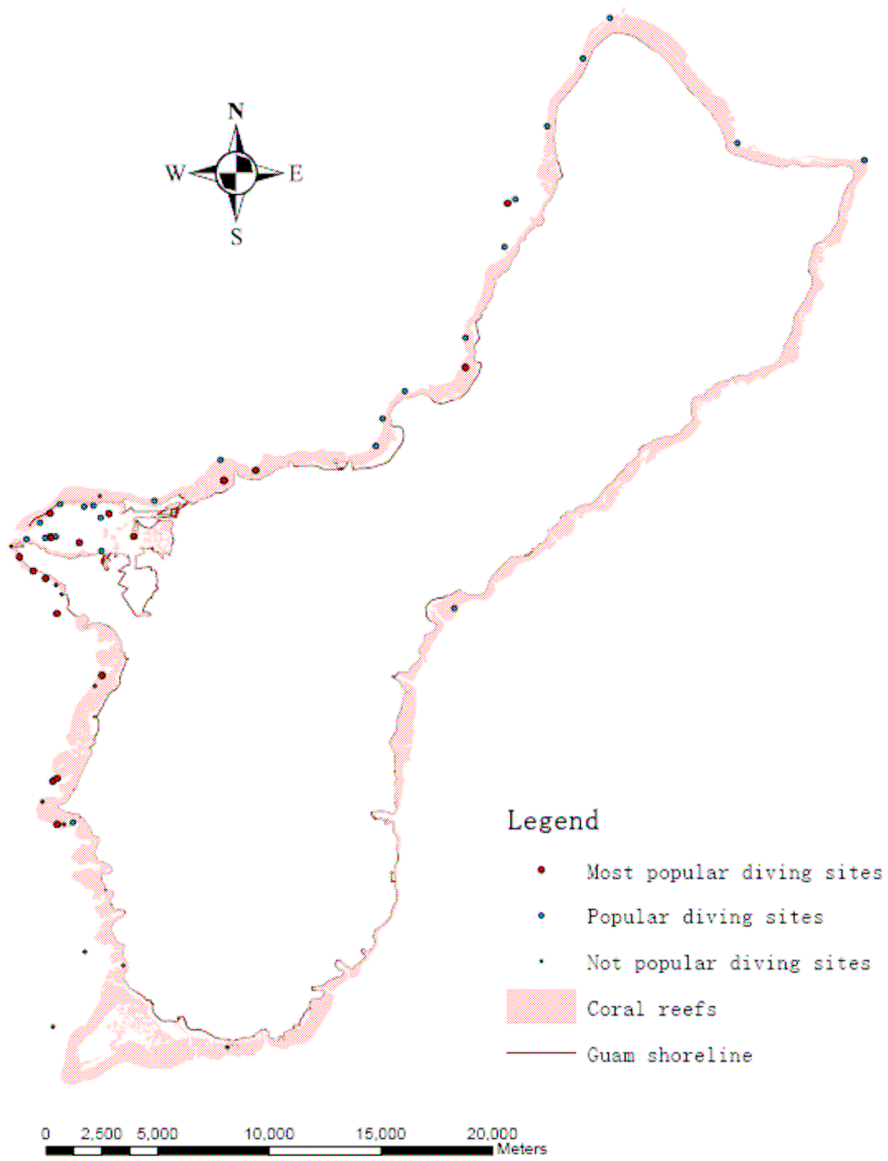

Figure 5.4 Diving and snorkeling sites in Guam

Secondly, reefs within each layer were sub-categorized based on their distance from diving and snorkeling spots. Coral reefs closer to diving and snorkeling sites are considered to have higher values in terms of diving and snorkeling. Following this principle, coral reefs were categorized in terms of distance to the dive and snorkeling spots. Coral reefs within 100 meters of diving sites were considered to have the highest value, within 100-200 meters a medium value, within 200-300 meters a low value, and beyond 300 meters no dive value at all (being too far from diving sites).

Monetary valuation

The next step was to spatially allocate the diving and snorkeling values. The total value was apportioned to each category based on the proportion of the score to the sum of all three scores. The reef-related diving and snorkeling value in Guam is US$8.69 million per year. As mentioned, the dive value of coral reefs is divided into three categories (i.e. most popular, popular and not popular). Their importance is different in terms of diving and snorkeling values. The most popular diving sites attract most of the divers; therefore, most of the diving and snorkeling revenues were attributed to the most popular sites. When assigning the weights, 10 out of 14 were given to the most popular sites. Popular sites are also more important than not popular sites. 3 out of 14 were assigned to popular diving sites. Not popular sites only received 1 out of 14.

Table 5.4 Categories and weights used in the diving and snorkeling model in Guam

Category	Weights	Reef area *(km^2)*	Score *(Weights*Reef area)*	Allocated value *(US$)*
Most Popular	10	1.51	15.1	5,581,412
Popular	3	2.32	6.96	2,572,624
Less Popular	1	1.45	1.45	535,963

As can be seen in Table 5.5, each category was divided into three sub-categories and weights were given to these three sub-categories. Most divers enjoyed the beautiful views underwater, which were within 100 m from diving sites. Some of the divers could travel 100-200m from the diving sites where they started. Few divers could travel 200-300m from the diving sites. Based on these facts, 60%, 30% and 10% were assigned to these three sub-categories, respectively.

Table 5.5 Sub-categories and weights used in the diving and snorkeling model in Guam

Category	Sub-category	Weight	Reef area *(km^2)*	Score *(Weights* Reef area)*	Allocated value *(US$)*	Value per unit area *($US\$.km^{-2}.year^{-1}$)*
Most Popular	H. (0-100m)	60%	0.18	0.11	1,737,154	9,650,857
	M. (100-200m)	30%	0.53	0.16	2,557,477	4,825,428
	L. (200-300m)	10%	0.8	0.08	1,286,781	1,608,476
Popular	H. (0-100m)	60%	0.27	0.16	787,836	2,917,911
	M. (100-200m)	30%	0.81	0.24	1,181,754	1,458,955
	L. (200-300m)	10%	1.24	0.12	603,035	486,319
Not Popular	H. (0-100m)	60%	0.21	0.13	186,551	888,337
	M. (100-200m)	30%	0.56	0.17	248,735	444,169
	L. (200-300m)	10%	0.68	0.07	100,678	148,056
Total			5.28		8,690,000	

After overlaying the three categories and adding up the corresponding value per unit area, we produced the map shown in Figure 5.5.

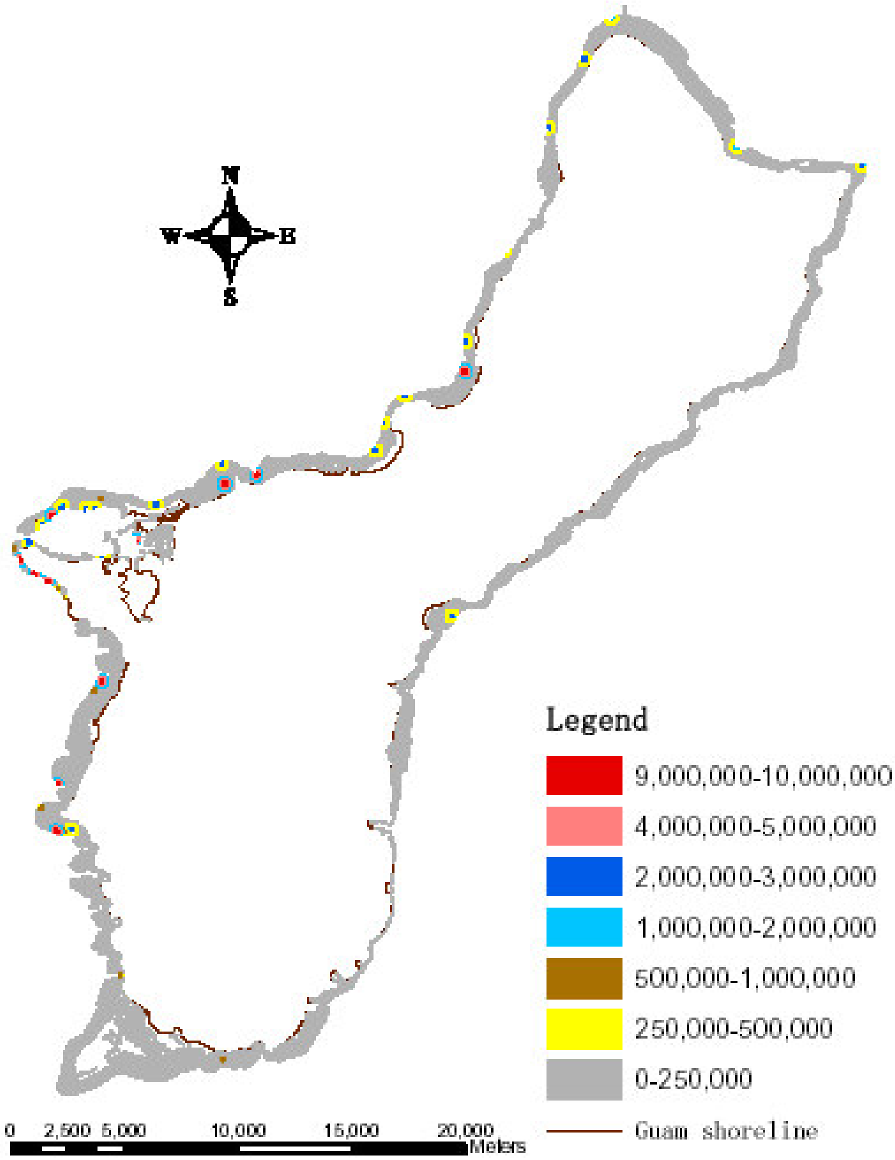

Figure 5.5 Distribution of reef-related diving and snorkeling value in Guam (US$/km^2)

5.4 Fisheries

To show the spatial distribution of the fishery value in Guam, coral reefs were mapped according to two main factors, both of which affect fisheries yields: fishing effort and reef habitat complexity. Due to inadequate reporting of the meta-data, the source of the fishing effort maps is unknown. The relationship between fishing effort and fisheries yield is easily understood. In theory, reef complexity plays a role in determining reef biomass (and hence fisheries yield): reef habitats with greater structural complexity have higher primary productivity (e.g. Adey & Steneck, 1985). Greater reef complexity also provides more opportunities for feeding, breeding and refuge from predation for fish and invertebrates. There are many studies, which demonstrate that the physical complexity of reefs is positively correlated with fish populations (i.e. Luckhurst and Luchhurst, 1978; Gladfelter *et al.,* 1980; Carpenter *et al.,* 1981; Sano *et al.,* 1984; Roberts and Ormond, 1987; Hixon and Beets, 1989; and Galzin *et al.,*1994).

Physical quantification

In the fishery component, we define nine yield categories corresponding to combinations of three effort factor levels (high=H, medium=M and low= L) and three complexity factor levels (high=H, medium=M and low=L). The categorization for these two variables is determined as follows:

- □1. Areas of fishing effort are delineated based principally on maps in which fishing areas with different fishing types are highlighted. Incorporated methods include common hook line (map 1), boat-based spear fishing (map 2), common net fishing (map 3), and shore-based spear fishing (map 4). Reefs overlapped by two or more fishing types are considered to be high effort areas. Reefs covered by only one fishing type are categorized as medium effort areas. The other reefs are considered to be low effort areas because there may be some unknown fishing activities. We use GIS software to identify the high, medium and low fishing effort areas. Buffer 500 m to the points in map 1, and 250m to the lines in map 2, 3 and 4 to get buffering zone 1,2,3 and 4. The reef areas overlapped by two and more buffering zones are high fishing effort areas. Reefs covered by only one buffering zone are medium fishing effort areas. The other reef areas are low fishing effort areas.
- Areas of *complexity* are delineated according to benthic habitat as classified by the National Oceanic and Atmospheric Administration (NOAA NCCOS,2005).

The definition of all nine categories and their interpretation is provided in Table 5.6.

*Table 5.6 Reef habitats and reef habitat complexity categories**

Habitat/ substrate type	Coral reef component	Reef habitat complexity
Linear reef		
Aggregated coral		High
Spur and groove		
Individual/aggregated patch reef		
Scattered coral/rock in unconsolidated sediment		
Colonized pavement/rock/boulder	Yes	Medium
Colonized pavement with sand channels		
Macro-algae or coralline algae		Low/Medium**
Reef rubble		
Uncolonized pavement/volcanic rock/boulder		Low
Uncolonized pavement with sand channels		
Sand or mud		
Mangrove	No	--
Sea grass		

* Areas classified as "unknown" were also considered as high complexity since these were only observed as a narrow strip along the reef crest where surf prevented image penetration. NOAA maps showed no lost image due to other factors (e.g. cloud cover, glare, turbidity).
** Medium when part of medium/high reef category; low when on low reef category.

To facilitate aggregation and quantification of these two different variables (see Table 5.7) with different units, we applied weights to the different fishery and complexity levels. These weights, in turn, determined the economic value attached to the specific area of coral reef.

- The weighting of H/M/L *fishing effort* factors as 0.6/0.3/0.1 largely follows the findings of a review of harvest data from 11 different countries by Stevenson & Marshall (1974). This gave a yield ratio of 2-5:1 tons/ km^2/year for well developed versus less developed inshore fisheries.
- The weighting of H/M/L *complexity* factors as 0.5/0.35/0.15 is based on studies of fishery yields for different reef habitats elsewhere. For instance, this is the approximate ratio between yields of good, moderate and high quality coral reefs given by McAllister (1988).

Table 5.7 Categories and Weights used in fishery model (1)

Fishing effort	Weight	Habitat complexity	Weight	Overall rating (effort/complexity)	Overall weight
High	0.6	High	0.50	High/High	0.300
High	0.6	Medium	0.35	High/Medium	0.210
High	0.6	Low	0.15	High/Low	0.090
Medium	0.3	High	0.50	Medium/High	0.150
Medium	0.3	Medium	0.35	Medium/ Medium	0.105
Medium	0.3	Low	0.15	Medium/Low	0.045
Low	0.1	High	0.50	Low/High	0.050
Low	0.1	Medium	0.35	Low/Medium	0.035
Low	0.1	Low	0.15	Low/Low	0.015

The next step in allocating the economic fishery value spatially involved combining the above weighting scheme with the actual area of reefs in each category. The result of this step is shown in Figure 5.6.

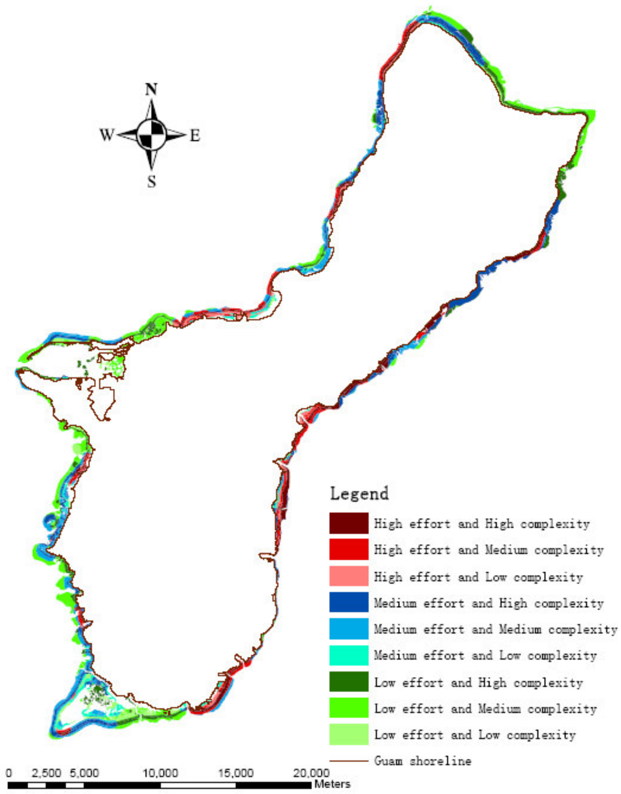

Figure 5.6 Coral reef fisheries in Guam

Monetary allocation

Next, GIS was used to express the economic fishery value per unit area in Guam. This procedure involves various steps. Firstly, the overall weight attached to each of the nine categories (second column in Table 5.8, adopted from Table 5.7) was multiplied by the area measured for each category (third column in Table 5.8). This resulted in the absolute importance of each category as fishery supply grounds (fourth column). Secondly, on the basis of this "importance" indicator, the annual value of Guam's reef-based fisheries (i.e. US$3.96 million), is allocated across the nine categories (see fifth column in Table 5.8). Finally, we determined the fishery value per unit area in Guam (last column in Table 5.8).

Table 5.8 Coral reef fishery model in Guam

Overall rating (effort/complexity)	Overall weight*	Area (km^2)	Absolute importance	Allocated fishery value (US$)	Fishery value per unit area ($US\$.km^{-2}.year^{-1}$)
High/High	0.30	6.31	1.89	992,626	157,310
High/Medium	0.21	5.88	1.23	645,994	109,863
High/Low	0.09	3.46	0.31	162,810	47,055
Medium/High	0.15	10.64	1.60	840,315	78,977
Medium/ Medium	0.105	12.20	1.28	672,257	55,103
Medium/Low	0.045	4.49	0.20	105,039	23,394
Low/High	0.05	7.95	0.40	210,079	26,425
Low/Medium	0.035	15.82	0.55	288,857	18,259
Low/Low	0.015	4.91	0.07	36,766	7,488
Total	1.00	71.66	7.54	3,954,744	55,188

Finally, we re-categorized the coral reefs in terms of fishery value per unit area (shown in the last column of Table 5.8) and converted this spatial information into a new map expressing the distribution of monetary fishery values in Guam (see Figure 5.7).

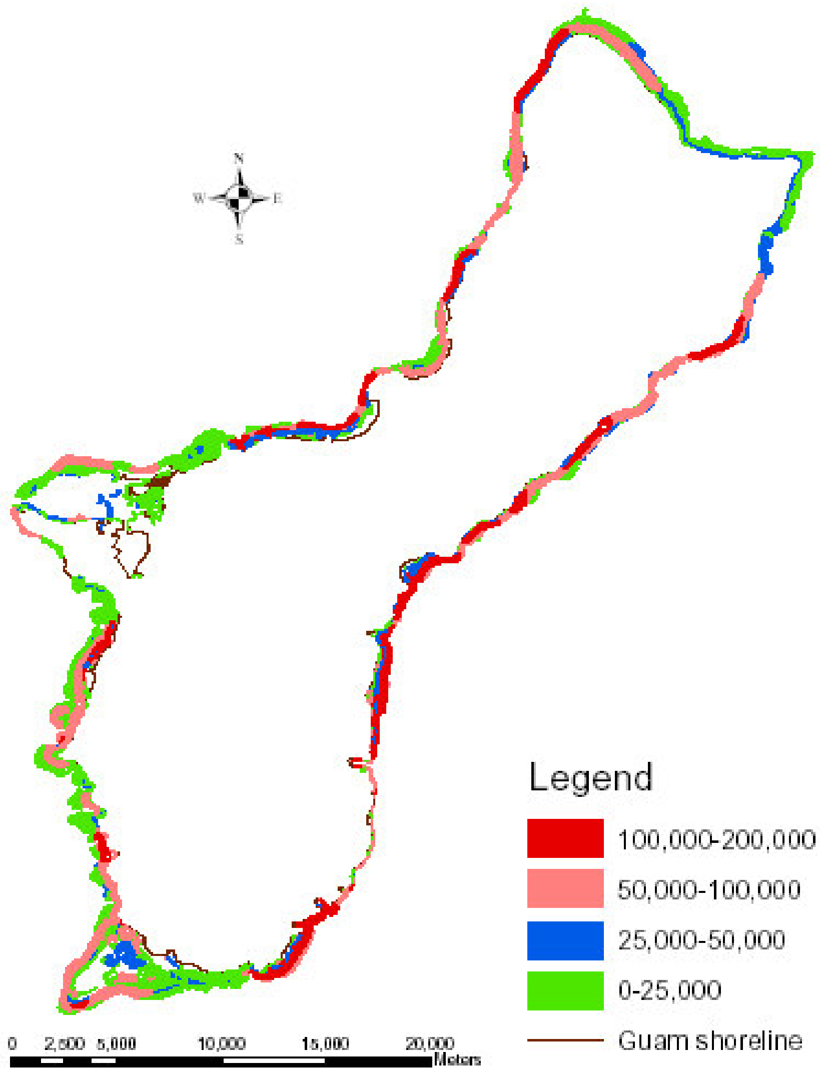

Figure 5.7 Coral reef fishery value distribution in Guam (Unit is US$.km^{-2}.year^{-1})

5.5 Amenity value

Coral reefs can provide amenities to people living within a certain distance of the coast, and the closer to the coast, the more amenity value can be enjoyed. The method based on this assumption includes the following steps. First, we divided the island into 4 parcels:

- Parcels on the coastline (0-100 meters inland)
- Parcels 100-250 meters inland
- Parcels 250-1000 meters inland
- Parcels beyond 1000 meters from the coastline

For technical reasons and reasons of simplification, we assumed (in the GIS analysis) that 'Parcel 4' is too far from the coastline to enjoy the amenity value of coral reefs. Therefore, we allocated the small amenity value of Parcel 4 (see previous Chapter) across the other parcels and limited our analysis to Parcels 1, 2 and 3, respectively.

Physical quantification

In the previous Chapter, the amenity value relating to Parcel 1, Parcel 2, Parcel 3 and Parcel 4 was calculated. We take Parcel 1 as an example to explain the method used to allocate these values. GIS software was used to identify coral reefs within 1000 meters of Parcel 1. Coral reefs identified here are categorized as coral reef layer 1. Parcels 2 and 3 were then used to produce coral reef layer 2 and layer 3. Each coral reef layer was divided into two parts, 0-500 meters from parcels and 500-1000 meters from parcels, because coral reefs closer to the coast have higher amenity values. The details can be seen in Figure 5.8.

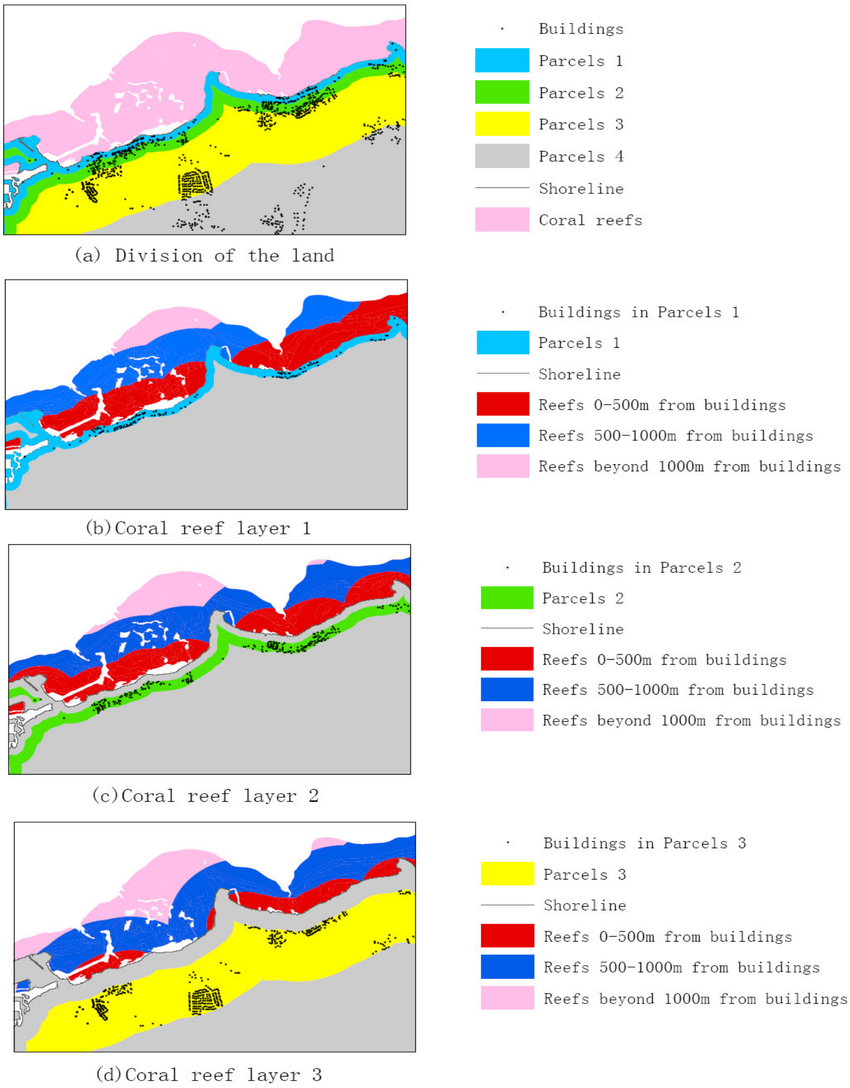

Figure 5.8 The method used in the distribution of amenity values of coral reefs

In addition, the area of each category was considered. The distribution of the amenity value in each layer was based on the proportion of the final score of each sub-category to the total final score of each layer. Categories and weights can be seen in Table 5.9. After allocating amenity values to every coral reef layer, the next step was to use GIS to overlay all these layers into one layer. Then the coral reefs were categorized according to the amenity value apportioned to them. The coral reef layer 1, 2 and 3 can be seen in Figure 5.9(a), (b) and (c).

Table 5.9 Coral reef amenity value model used in Guam (1st part)

Category	Sub-category	Weight	Area (km^2)	Score/total score
Reef layer 1	0-500m from parcels	0.7	14.59	10.21 / 14.9
	500-1000m from parcels	0.3	15.65	4.69 / 14.9
Reef layer 2	0-500m from parcels	0.7	10.81	7.57 / 13.05
	500-1000m from parcels	0.3	18.26	5.48 / 13.05
Reef layer 3	0-500m from parcels	0.7	4.68	3.28 / 9.45
	500-1000m from parcels	0.3	20.56	6.17 / 9.45

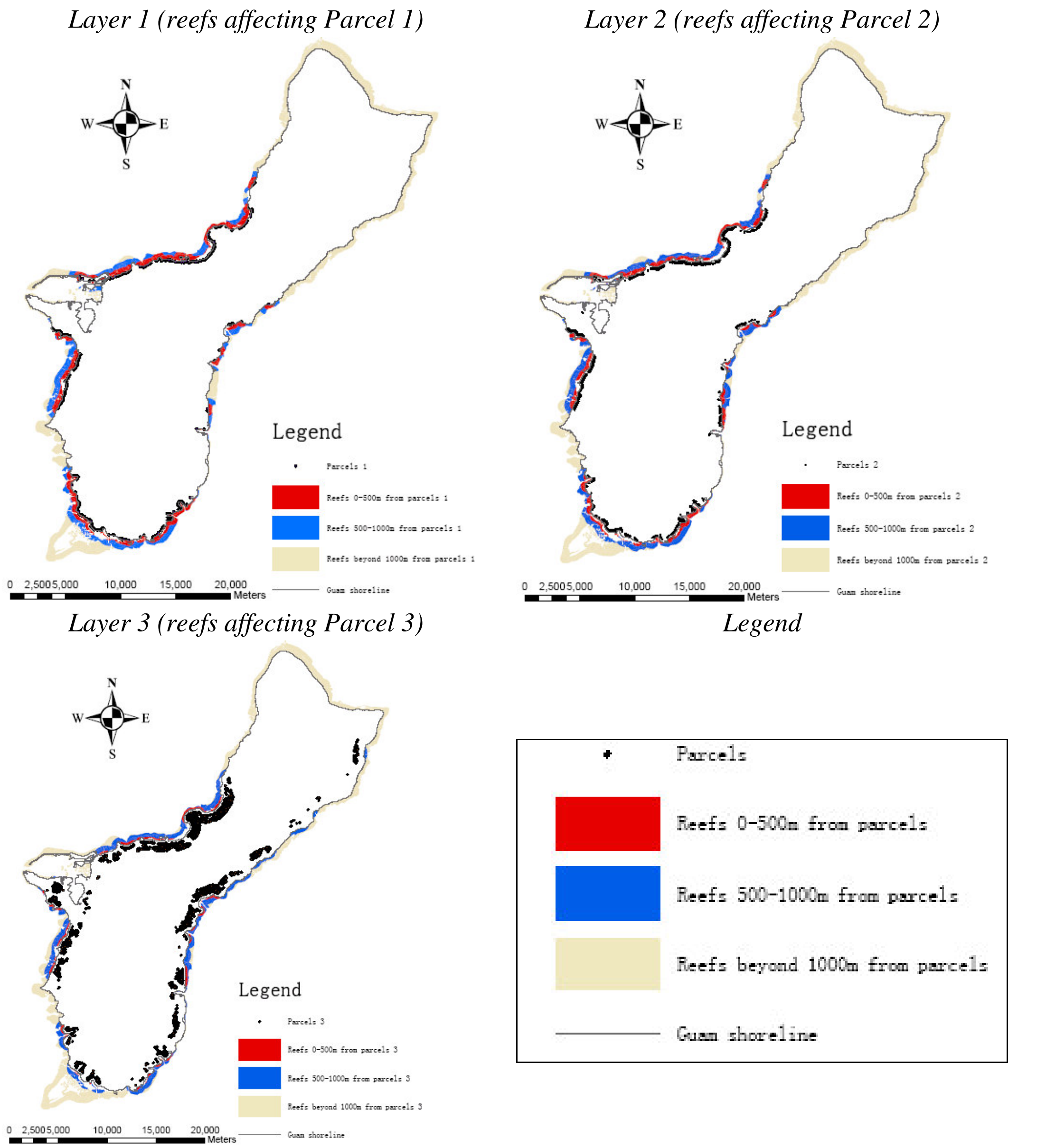

Figure 5.9 Coral reef amenities in Guam (layer 1, 2 and 3)

Monetary valuation

As calculated earlier, annual amenity values of Parcels 1, 2 and 3 are US$7.7 million, US$4.6 million and US$3.1 million, respectively. Combining these values and the area of each sub-category, generated the results displayed in Table 5.10. Following the assumption that coral reefs closer to the coastline have higher amenity values, in each layer a 70% weight was attached to coral reefs located within 500 meters of the coastline and 30% was assigned to coral reefs within 500-1000 meters of the coast.

Table 5.10 Coral reef amenity value model used in Guam (2nd part)

Category	Sub-category	Allocated amenity value (US$)	Amenity value per unit area (US$.km^{-2}.year^{-1})
Reef layer 1	0-500m from parcels	3,288,522	225,374
	500-1000m from parcels	1,511,478	96,589
Reef layer 2	0-500m from parcels	1,663,272	153,882
	500-1000m from parcels	1,204,260	65,950
Reef layer 3	0-500m from parcels	670,693	143,205
	500-1000m from parcels	1,261,774	61,373

The next step was to overlay the three coral reef layers and add up the corresponding amenity values per unit area. The result is shown in Figure 5.10.

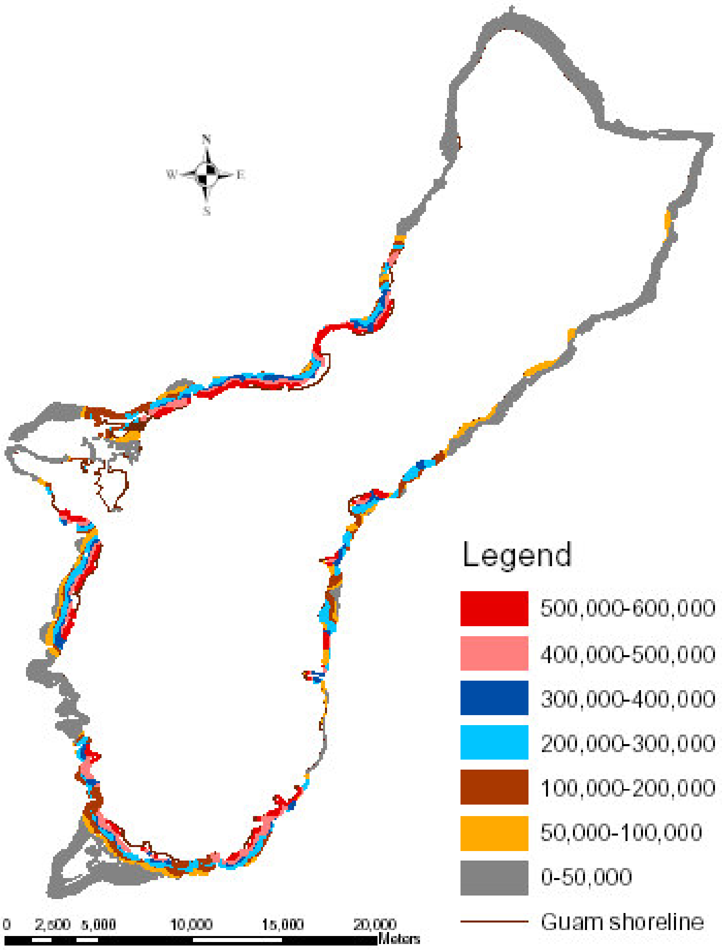

Figure 5.10 Coral reef amenity value in Guam (Unit is US$.km-2.year-1)

5.6 Coastal protection

The principle used to determine the spatial allocation of the value of coastal protection is that without the protection of coral reefs, the waves and storm surges would reach higher elevations and cause more serious damage. The maps used include the elevation contour map of Guam and a map in which the location of buildings in Guam is shown.

Physical quantification

The method adopted to spatially value the coastal protection role of coral reefs in Guam involved two main steps. Firstly, GIS was used to analyze the potential damage caused by tropical cyclones (specifically caused by waves and storm surges), from west and east of Guam. Tropical cyclones from different directions inflict different damage to the islands. For instance, the infrastructure and coastal properties located on the west of one island are subject to greater potential losses if the tropical cyclone hits the west of the island. One assumption requires specific attention: without the protection of coral reefs, the heights of waves and storm surges would be double. This assumption is based on the knowledge that the physical structure of coral reefs dissipates much of the force of waves: up to 77% in the case of discontinuous reefs, and more for continuous systems (UN Atlas of the Oceans).

The second step was to combine the results of the first step to produce the thematic map showing the spatial distribution of coastal protection values of coral reefs in Guam. Taking into account the fact that most tropical storms in Guam come from the east (80%) and only 20% from the west, we compared the coral reefs' coastal protection function for two situations: (1) storm damage *with* coral reefs present and (2) storm damage *without* the protection of coral reefs. Potential heights of waves and storm surges with and without protection of coral reefs can be seen in Figure 4.17.

-a- West (20%) *-b- East (80%)*

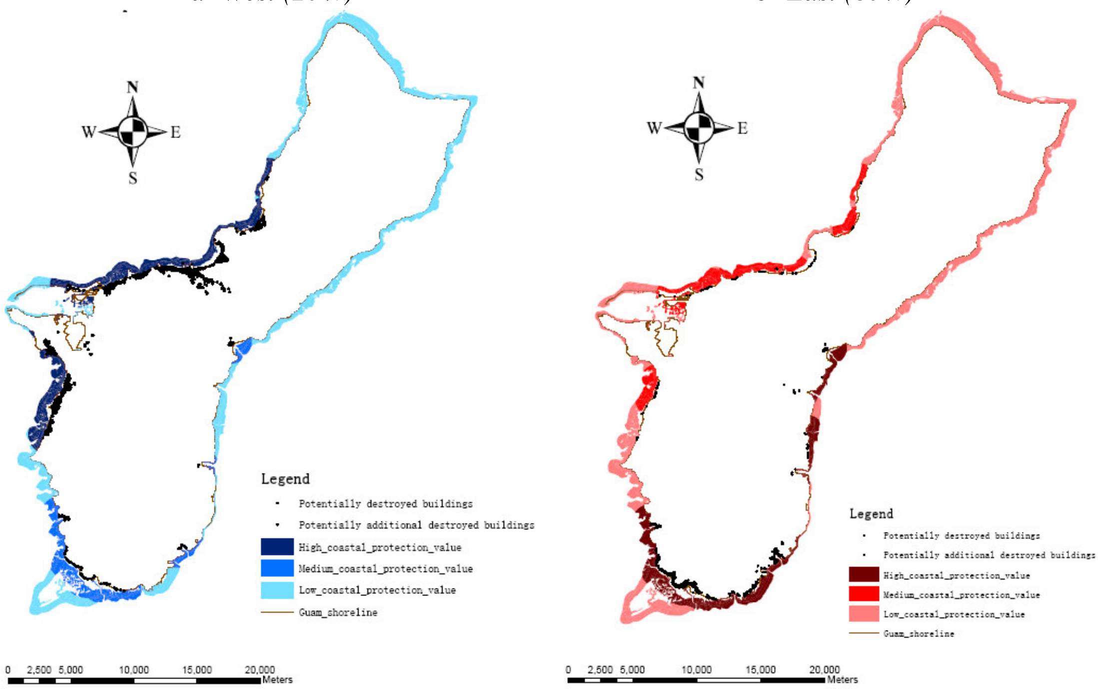

Figure 5.11 Potential damage due to tropical storms from the west and the east of Guam

As explained earlier, the situation without the protection of coral reefs is expected to cause the potential heights of waves and storm surges to double (compared to a situation with coral reefs). The detailed damage caused by tropical storms can be seen in Figure 5.11(a) and (b). Coral reef values were categorized according to the density of potentially vulnerable buildings. This meant that higher densities of potentially vulnerable buildings led to higher coastal protection values of coral reefs.

Monetary quantification

According to the previous calculation, under the 'without the protection of coral reefs' scenario, one substantial tropical storm from the west would result in extra damage worth around US$14 million; the extra loss would be US$7 million if the storm was from east (see Table 5.11). The process of assigning weights was based on the density of additional buildings that could potentially be destroyed. The greater the density of these buildings, the higher the coastal protection value of nearby coral reefs. 60% was given to the high coastal protection value of coral reefs, which meant these coral reefs can protect 60% of these vulnerable buildings. 30% and 10% were assigned to medium and low coastal protection values of coral reefs, respectively.

Table 5.11 Coral reef coastal protection monetary value model used in Guam (1)

Tropical storm direction	Average loss each substantial storm(US$)	Probability	Sub-category	Weights
			High value	60%
West	14,000,000	20%	Medium value	30%
			Low value	10%
			High value	60%
East	7,000,000	80%	Medium value	30%
			Low value	10%

Following the same approach to that used to generate the other economic values, the combination of the relative scores with the gross economic value allowed for the estimation of the coastal protection values per unit of area (Table 5.12). The average loss caused by a substantial tropical storm in Guam is:

US$1,400,000*20% + US$7,000,000*80% = US$8,400,000

The subcategory of "west-high value" is taken as an example to show how "allocated value" and "value per unit area" were calculated in this section.

Total score of "west" = 11.35 + 3.22 + 4.21 = 18.78
Allocated value= US$1,400,000 * 20% * (11.35/18.78) = US$1,693,155
Value per unit area = Allocated value / Reef area = US$1,814,095 / 18.92 = US$89,490

The other values were calculated in the same way.

Table 5.12 Coral reef coastal protection monetary model used in Guam (2)

Tropical storm direction	Area (km^2)	Score	Allocated value (US$)	Coastal protection value per unit area (US$.$km^{-2}$.$year^{-1}$)
	18.92	11.35	1,693,155	89,490
West	10.72	3.22	479,668	44,745
	42.05	4.21	627,177	14,915
	16.11	9.67	3,041,330	188,785
East	12.87	3.86	1,214,833	94,393
	42.71	4.27	1,343,836	31,464

After overlaying the two maps shown in Figure 5.11 (a) and (b) and adding up the corresponding coastal protection values per unit area, the coral reefs were re-categorized in terms of monetary value (see Figure 5.12).

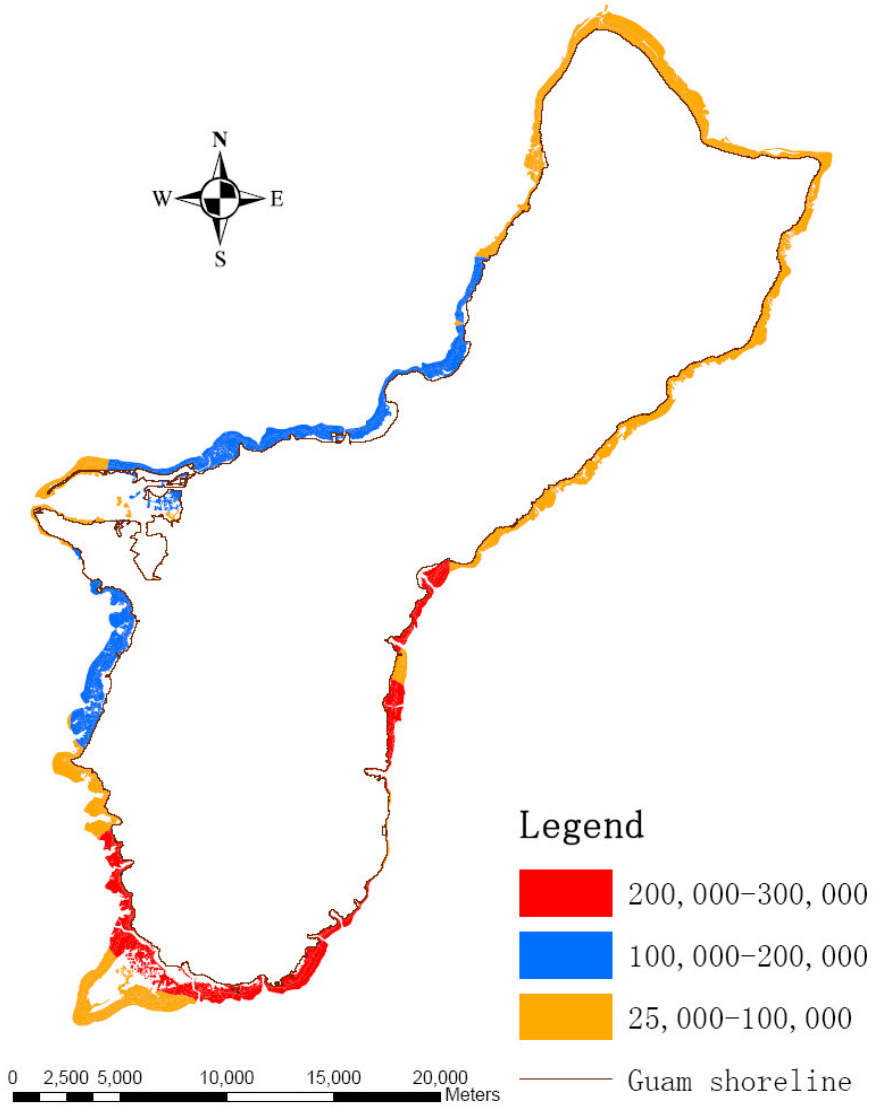

Figure 5.12 Distribution of reef coastal protection value (Unit is US$.km-2.year-1)

5.7 Biodiversity

The biodiversity value can be spatially allocated on the basis of a number of biological indicators, such as diversity, coral cover, 3-D structure, rareness, etc. Because the study has to relly on the available maps, the selected method to allocate the biological value in this study was based on the reef cover type, i.e. the dominant biological components of the coral reefs.[5]Following a report by the National Oceanic and Atmospheric Administration (NOAA NCCOS, 2005), these cover types were defined in a collapsible hierarchy of eight major classes, combined with the percentage of the predominant cover type.

Physical quantification

When determining the weights of cover types, cover types with higher rankings on the list of eight major classes were given higher weights. This method of biological valuation is based on the cover type of reefs. The benthic habitat map produced by NOAA supplied the information needed. Coral reefs can be divided into the following categories (shown in Figure 5.13) in terms of cover types and percentage cover of live coral.

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5 The authors recognize that coral cover is a sub-optimal indicator, but as long as a map is lacking in which all biodiversity components are represented, we do not have a better alternative, but to follow this route.

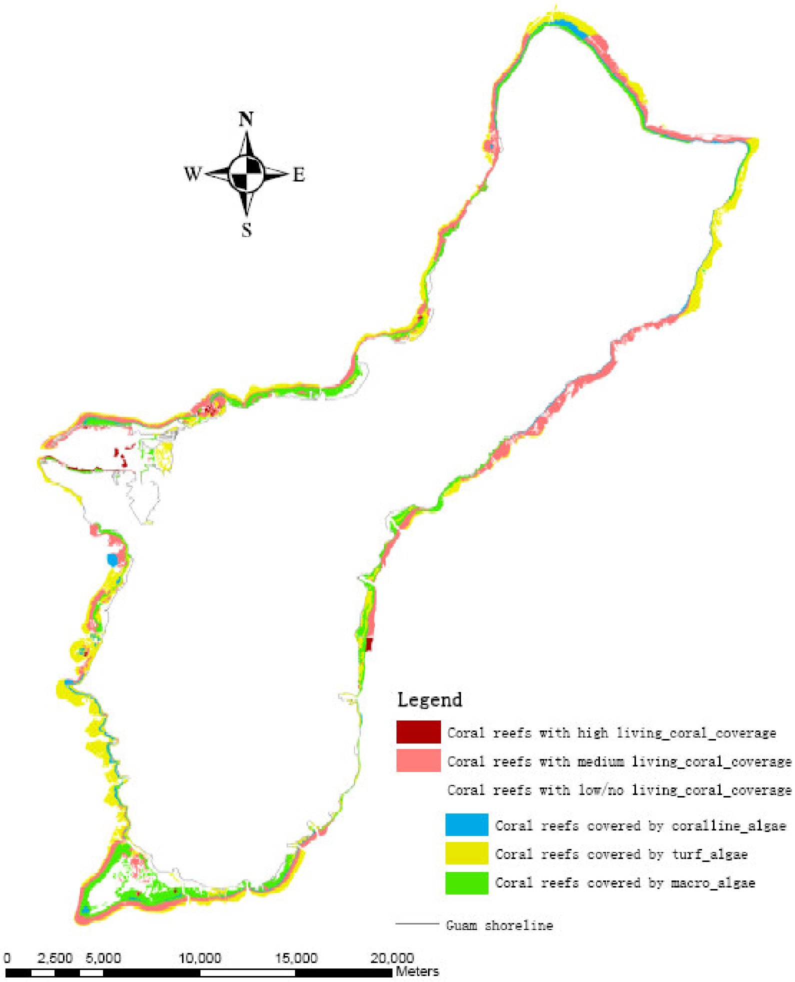

Figure 5.13 Coral reef biodiversity in Guam

Monetary quantification

The biodiversity value of coral reefs is around US$2 million per year. The weights and categories can be seen in Table 5.13. With regard to assigning weights, 70% was given to reefs covered by living coral because they are more ecologically important and valuable than those covered by algae. Within this 70%, 45% was assigned to high living coral coverage and 25% to medium coverage. 15%, 10% and 5% were assigned to coralline algae, turf algae and macro-algae, respectively.

Table 5.13 Biodiversity monetary model used in Guam

Category (cover type)	Weights	Area (km^2)	Score	Allocated value (US$)	Biodiversity value per unit area (US$.$km^{-2}$.$year^{-1}$)
High living coral cover	45%	0.88	0.40	75,257	85,519
Medium living c. cover	25%	24.65	6.16	1,171,133	47,510
Coralline algae	15%	3.82	0.57	108,894	28,506
Turf algae	10%	25.62	2.56	486,887	19,004
Macro-algae	5%	16.61	0.83	157,830	9,502
Total	100%	71.58	10.52	2,000,000	--

The map expressing the spatial allocation of the biodiversity value per unit area in Guam is shown in Figure 5.14.

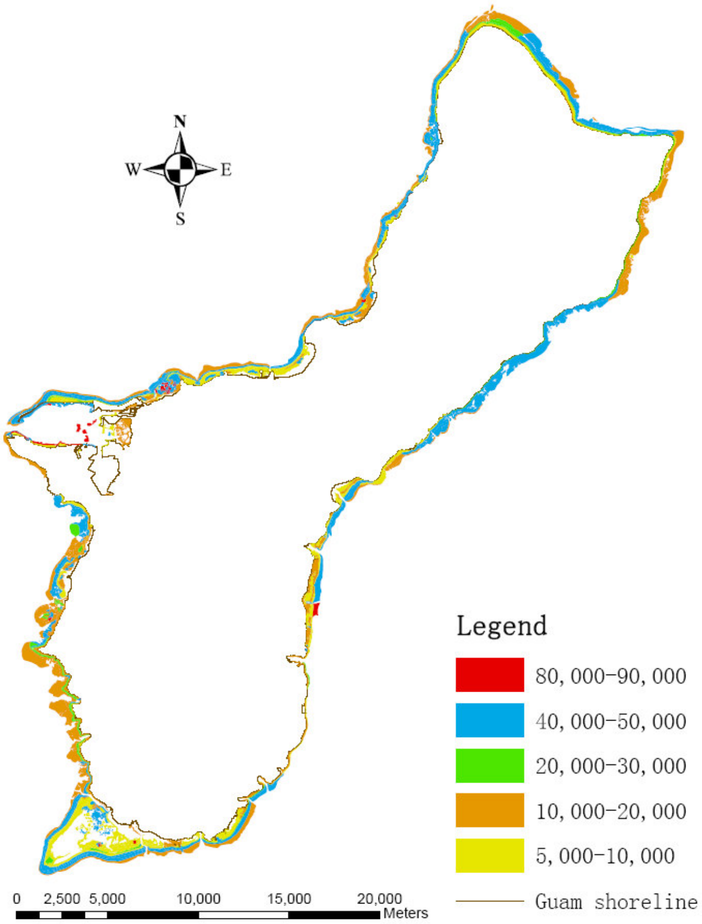

Figure 5.14 Coral reef biodiversity value distribution (Unit is US$.km-2.year-1)

5.8 Synthesis

As demonstrated in the previous sections, coral reefs play a significant role in the economy and culture of Guam. However, recent economic developments pose serious threats to the marine ecosystems in Guam, thereby jeopardizing the economic benefits of coral reefs. Many of these threats can be avoided or minimized through effective policy interventions. However, due to a lack of financial means, only a limited number of potential interventions can be implemented. Therefore, a comprehensive selection tool is needed to help choose the most effective interventions. In this section, we demonstrate how this tool might be developed, using a combination of GIS and economic valuation.

Aggregation of economic values into Total Economic Value (TEV)

Earlier sections provided various maps of the individual values of Guam's reefs. To get a more general understanding of the variation in economic values between the different reefs, we created a map in which all five monetary maps are combined. Such an aggregation may be open to criticism, given that these values differ too much in nature and size, and that combining them to produce one Total Economic Value (TEV) map is not scientifically sound. After all, some of the values are very explicit (i.e. divers revenues) while others are more implicit (i.e. coastal protection value). Nevertheless, one argument in favor of combining the individual values is that ultimately, they benefit the citizens of Guam, and therefore they can be combined. shows the result of the aggregation process.

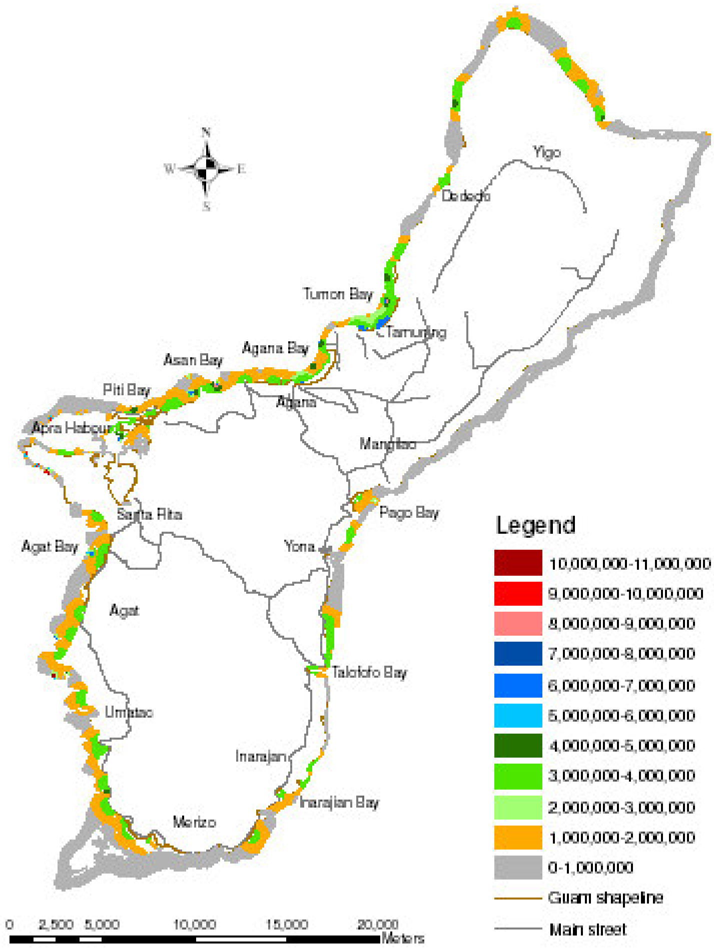

Figure 5.15 Total economic value of coral reefs in Guam (Unit is US$.km-2.year-1)

Threats to coral reefs of Guam

Guam's coral reef ecosystems are under pressure from various types of human-induced threats. These threats differ greatly in nature and magnitude.

Sedimentation is the major anthropogenic threat to the central and southern reefs. The eastern reefs along the central and southern portions of the island are heavily affected by sedimentation and freshwater runoff during the rainy season (June to November). Sediment accumulation on reefs has been documented to substantially reduce both coral diversity and abundance (Rogers et al., 2002).

During the early 1990s, a road project along the southern shores of the island resulted in particularly heavy sedimentation. It affected a 10 km section of fringing reefs, killing all the coral. Most of the fringing reefs along the southern part of the island, and along the south-western shores, are in poor to fair condition (Kelty et al., 2004).

In the inner Apra Harbour, reefs have been impacted by freshwater runoff, sediment and thermal discharges from the island's main power generation facilities. These are located on Cabras Island, in the northern portion of Apra Harbor. Water that is used to cool the generators has killed coral (Richmond and Davis, 2002).

Box 5.1 Local Action Strategy

In August 2002, the Guam Coral Reef Initiative Coordinating Committee (GCRICC) began the process of selecting and prioritizing the main threats to local coral reefs. This formed the basis for the Local Action Strategy (LAS) efforts for the following three years. By February 2003, the GCRICC had identified local navigators and drafted the LAS for a number of areas. Among the numerous benefits realized through these efforts, the LAS process significantly expanded and enhanced the network of stakeholder groups working on coral reef issues.

- Members of the Guam Watershed Planning Committee (WPC), a group of local, federal, and non-governmental agencies involved primarily with watershed restoration, have become involved in the LAS development, and members of the GCRICC now participate in the WPC.
- In addition, the University of Guam Marine Laboratory and Water and Environmental Research Institute, guided by the needs of the local natural resource agencies, have shifted much of their focus towards management driven research.
- The Guam Visitors Bureau and the tourism industry are working with the natural resources agencies to market Guam's coral reefs (and in particular Guam's marine preserves) to the one million visitors that come to the island yearly. A new awareness of the economic value of coral reef resources is beginning to create a sense of stewardship in the sector, which was absent during the economic boom of the 1980s and recession of the 1990s.

Ultimately these new partnerships and increased support for improving the health of Guam's coral reefs have resulted in the LAS development focusing on a number of concrete interventions, such as addressing land-based sources of pollution (US$1,071,823 are the estimated LAS project implementation costs), fisheries management (US$1,200,963), lack of public awareness (US$462,134) and recreational misuse/overuse (US$364,500)

Source: U.S. Coral Reef Task Force, 2002, www.coralreef.gov

Agana, Tumon, and Piti Bay (also known as Tapungun) are heavily used by people. The inner areas of these bays are in relatively poor condition, affected by discharges from the land. West Agana has a sewage treatment plant built on the reef flat, with a pipe that discharges into 60 ft of water. This results in serious eutrophication (Kelty et al., 2004).

In 2002, the U.S. Coral Reef Task Force identified the need for more focused action at the local level to reduce key threats to coral reefs. The Task Force called for the development of Local Action Strategies (LAS) in each of the seven states and territories that possess significant coral reef resources. The outcome of this prioritization process is shown in Box 5.2. As can be seen in Figure 5.16, these anthropogenic threats are not spatially constant, but vary between the different reefs.

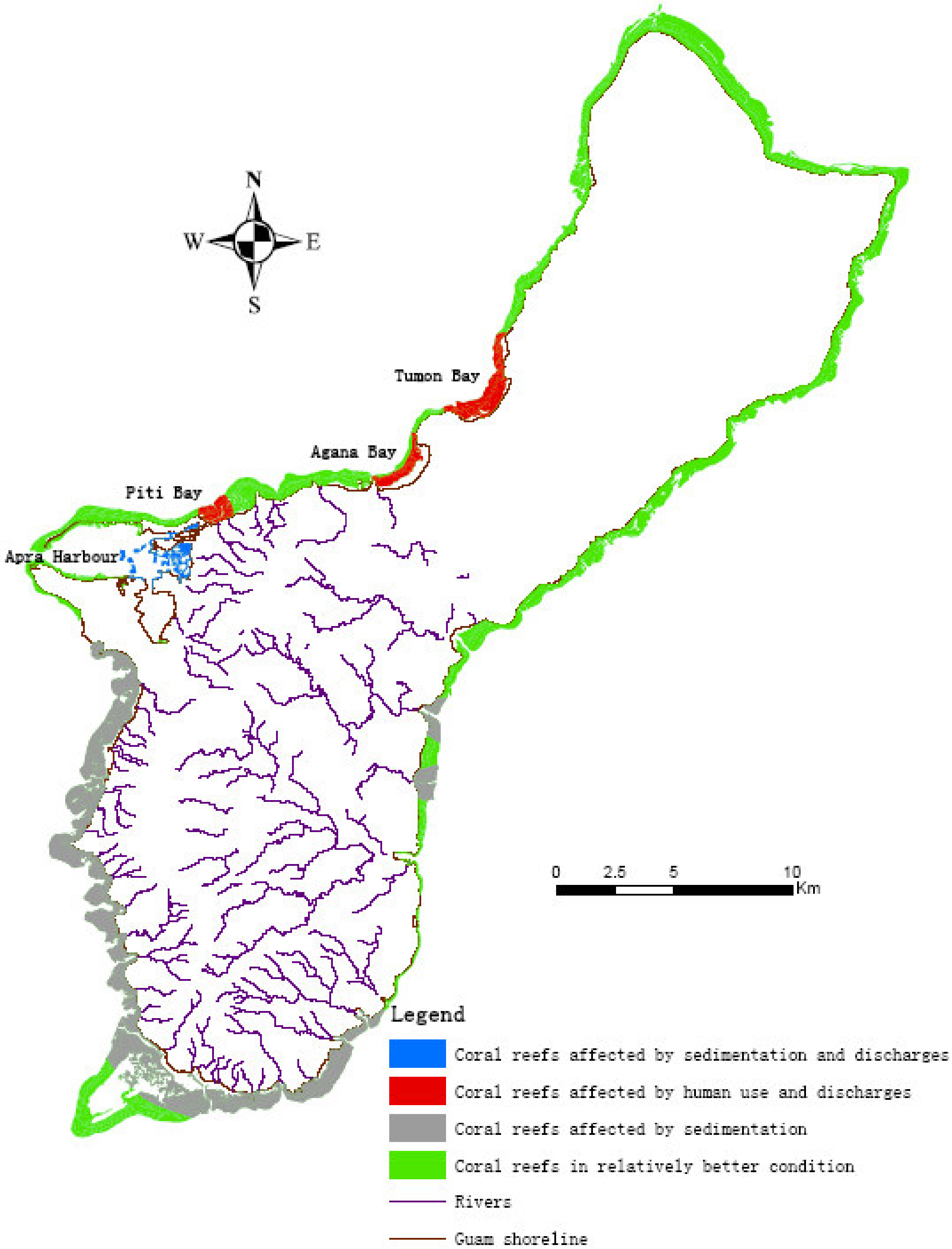

Figure 5.16 Anthropogenic threats to coral reefs in Guam

Box 5.2 Population growth and coral reefs

Main threats to Guam's coral reef health include land-based sources of pollution, increased patterns of use and/or misuse, and frequency of natural disturbances. Part of this is due to the gradual increase in Guam's population. Guam experienced a 16.3% population increase from 1990 to 2000, with the 2000 population estimated at 154,805 individuals. This equates to a population density of 737.7 individuals/m2 (U.S. Census Bureau, 2003). The rate of growth from 1990-2000 is the culmination of three decades of strong growth: The population from 1970 to 1980 grew by 24.7%, and the population from 1980 to 1990 grew by 25.7%. Predictions by the US Census Bureau estimate that the growth rate will decrease over the next 50 years, but the population in 2050 is expected to reach approximately 242,000 (U.S. Census Bureau International Programs Center, 2003).

Population increases and economic growth have accelerated land development, especially in the late 1980's and early 1990's. Guam has also seen a substantial increase in the number of annual visitors. The number of hotel rooms on Guam increased from 50 in 1963 to 10,110 in 2000. The fast pace of development was not always restrained by proper development practices, and Guam's reefs suffered. The southern half of Guam, with its hilly interior and erodable volcanic soils provides a prime example. The hilly interior precludes development on all but coastal areas. Inadequate roads became a problem for southern residents, and in the early 1990's a 10km stretch of coastal road linking two of the southern villages was completely upgraded. Proper development practices were not observed, and the engineering designs (large roadside culverts on the road shoulder funnel rainwater directly to the ocean) were not tailored for small coastal islands. As a result, the section of reef abutting this region of the coast was inundated with freshwater runoff carrying everything from sediment to petroleum products and nutrients, killing much of the coral (Dr. Robert Richmond, UOGML, personal observation).

Comparing TEV and threats

Having compared the distribution of total economic values of coral reefs (shown in Figure 5.15) and anthropogenic threats to coral reefs (shown in Figure 5.16), we conclude that, in general, more valuable coral reefs tend to be in relatively poor condition, and face more serious anthropogenic threats.

In terms of value per unit area, the most valuable coral reefs are located within 200m of the most popular diving and snorkeling spots (see Table 5.14). Because diving sites are normally far from the coastline, coral reefs around them are in relatively good conditions. However, some of these valuable coral reefs have been affected by discharges and sedimentation from the land. These valuable coral reefs should be properly preserved to maintain their extremely high economic value.

Coral reefs in the inner areas of Tumon, Agana and Piti Bays are also valuable, largely because these bays are the most popular general tourist sites in Guam. Most of the major hotels, and many comfortable beaches and parks are located there. Therefore, the coral reefs closest to these bays are more valuable than those in other places. Because of over-exploitation and a lack of proper planning and management, it is unavoidable that coral reefs are negatively affected by the pressures of human use and discharges from the land. Effective action should be taken to rehabilitate these threatened coral reefs, like building more wastewater treatment plants to reduce discharges and sewage from the land and planning tourism more carefully so that resources are not over-exploited in the future.

Table 5.14 Spatial variation of values of coral reefs in Guam

Value category	Area (km^2)
Range $0-$1,000,000	37.62
Range $1,000,000-$2,000,000	18.51
Range $2,000,000-$3,000,000	1.64
Range $3,000,000-$4,000,000	11.68
Range $4,000,000-$5,000,000	0.37
Range $5,000,000-$6,000,000	0.21
Range $6,000,000-$7,000,000	0.71
Range $7,000,000-$8,000,000	0.01
Range $8,000,000-$9,000,000	0.07
Range $9,000,000-$10,000,000	0.05
Range $10,000,000-$11,000,000	0.72
Total	71.59

Coral reefs along the southern coastline of Guam also have relatively high economic values because of their significant role in tourism, fisheries, coastal protection and supplying amenities. But they are in poor condition due to serious sedimentation. Proper land planning and management are needed to diminish this serious sedimentation and protect these valuable coral reefs. The coral reefs located in the north and northeast of the island are in better condition, but their economic value is relatively low. Another positive finding is that coral reefs in the very north of Guam can be considered highly valuable as well as being in relatively good condition.

In summary, the conservation priorities are those coral reefs located in the Tumon, Agana and Piti Bay. At the same time, coral reefs along the southern coastline also require protection, albeit at a different level.

6. Conclusions

6.1 Introduction

Coral reefs are an important element in Guam's economy, supporting tourism, coastal protection, fisheries and academic research. At the same time, reefs are also deeply embedded in the island's culture. For example, the migratory return of traditional fish species such as ti'ao (baby goat fish), and manahak (baby rabbit fish) are times of special significance, bringing friends and families together to share in the harvest. Because several of the above-mentioned goods and services are not traded on the market, measuring their economic importance is not a straightforward task.

The objective of this study was to carry out such an economic valuation, focusing on the five main uses of coral reefs in Guam. Some of these are extractive uses, such as fisheries (i); others are non-extractive, such as recreation/tourism (ii), cultural/traditional uses (iii), and education and research (iv). Finally, some are indirect uses, such as shoreline/infrastructure protection (v). With a better understanding of the economic importance of coral reefs, Guam's decision makers can design their policies in a more efficient manner, utilizing their limited funds in the most cost-effective way.

6.2 Conclusions

The results of the study were derived through four major research methodologies:

- Household survey
- Discrete choice experiment
- Total Economic Value Calculation
- Spatial analysis

Household survey: The main purpose of the household survey (of 400 local residents) was to determine the nature and level of the use and non-use values of coral reefs, from the perspectives of local communities in Guam. The survey covered a number of issues, such as respondents' level of beach and marine recreation, environmental awareness, fishing activities and the importance of fish in their diet. The survey showed that the westernization of Guam society has not fully disconnected local residents from the ocean. Albeit to a lesser extent than in the past, citizens of Guam still use the marine environment surrounding the island for fishing and recreational activities. As such, people are concerned about further deterioration of the marine environment, and they support policy interventions that aim to reverse this negative trend. In fact, they have clear ideas about the direction in which these policies should move. This was an important and encouraging finding of the survey.

Discrete choice experiment: To estimate the economic value of the above-mentioned non-market values, the Discrete Choice Experiment (DCE) was used. In the DCE, respondents were presented with a series of choice sets, composed of different attributes associated with reefs and their management (e.g. recreation, fisheries, tax payments). They were then asked to choose between these choice sets. Guam's residents appeared to place a similar value on the ability of reefs to provide local recreational benefits and supply culturally significant fish species. In addition, the results indicate that maintaining reef fish and seafood stocks at a level that can support the culture of food sharing is very important. Guam's residents favor the ban on destructive fishing practices but are most concerned about the effects of pollution and its management. They are generally willing to pay more tax for this issue to be addressed.

Total Economic Value: At the core of the economic value of coral reefs are the various ecosystem functions associated with these marine systems. These, in turn, translate into reef-associated goods and services used by Guam society (e.g. tourism, fisheries). The sum of these values forms the Total Economic Value (TEV), representing the entire economic importance of Guam's marine environment. The tourism industry in general is by far the greatest beneficiary of the services provided by coral reefs in Guam. At US$141 million per year, the TEV of these marine systems accounts for about 4% of the Gross National Product (GDP) of Guam. This economic importance is not entirely reflected in the funds made available by the Government of Guam to manage the reefs.

Spatial analysis: The spatial dimension of interactions between the economy and coral reef is crucial in understanding their economic value. Generally, the beneficiaries of reefs' goods and services are not spread evenly throughout Guam, but vary from location to location. Therefore, Geographic Information System (GIS) tools were used to increase our understanding of this spatial variation in economic values. This helped us to direct policy interventions more effectively. Although the average value of reefs per square kilometer amounted to US$2 million, the highest value per square kilometer was US$15 million. This highest value category measured only 200 square meters and comprised the most popular diving and snorkeling sites. Having compared the distribution of reefs' total economic value and their anthropogenic threats, we conclude that, in general, the more valuable the reef, the poorer their condition and the greater their threats.

6.3 Recommendations

To provide economically-sound guidance to decision makers on the management of coral reefs, several types of information need to be available:

- On *economic values*: To what extent do the various sectors benefit from the goods and services provided by coral reefs in Guam? Within the 72 square kilometer 'coral reef zone' along Guam's coastline, which reefs play the most important role in the provision of these benefits?
- On *threats*: What are the main threats to coral reefs in Guam? What are the origins of these threats and which reefs do they affect most?
- On *management interventions*: Which measures should be taken to prevent further degradation of coral reefs in Guam, and what financial costs are involved?
- On *financial mechanisms*: Which funds can be accessed to finance the management of coral reefs in Guam? Can novel (market-based) instruments be used to generate sustainable funds for management?

If all this information were available, one could subsequently: (1) identify both the most valuable, and most seriously threatened, reefs in Guam, (2) determine the type of threat jeopardizing a specific reef and select a number of potentially worthwhile interventions, (3) evaluate the economic benefits and financial costs associated with these interventions, while simultaneously (4) finding sustainable sources of funding for management interventions.

Clearly, the means available during this study were insufficient to complete all four steps listed above. This study carried out step 1, and partly step 2. At the same time, some knowledge was generated to support step 4. Step 3 remains unanswered at present; however, Guam's Local Action Strategy (LAS) provides a good basis for completing this step. In other words, pieces of the puzzle have been developed, but there are still insufficient pieces to complete the analysis. Nevertheless, several specific policy recommendations can already be provided on the basis of the outcomes generated in this study.

Recommendation 1: Make use of the cultural importance residents place on marine ecosystems to improve coral reef management

The survey and choice experiment revealed a strong link between local residents and their marine ecosystems. Most residents are preoccupied about the state of the marine environment and favor stringent measures geared towards its protection. Water pollution followed by destructive fishing methods are their greatest concerns. These concerns can be used to create increased local support for coral reef management. Residents are also a potential source of funding, since a significant share of respondents indicated they would be willing to pay higher taxes for improved marine management. At the same time, residents' bond with reefs could be further enhanced by encouraging children to learn to swim, as well as by launching campaigns on the importance of coral reefs for Guam.

Recommendation 2: Actively involve the tourism industry in the development of sustainable coral reef management.

More than any other sector in Guam, the tourism industry is a key player in the management of coral reefs. Not only does this sector benefit the most from the presence of abundant and healthy coral reefs, but it is also one of the major causes of marine degradation. Moreover, because of the large number of tourists, this sector can provide the critical mass needed to generate sustainable funding for coral reef management. With this objective in mind, an environmental tourist tax could be introduced, representative of the environmental damage caused by visitors. Similarly, user fees for divers and snorkelers could be introduced more extensively. Such taxes and fees are unlikely to discourage visitors from coming to Guam, especially if it is clearly communicated that the resulting funds are spent on coral reef management only. The advantage of this approach is that it follows the 'polluter pays' principle.

Recommendation 3: Limit the commercial consumptive use of coral reefs by prioritizing stronger enforcement and protection of marine protected areas in Guam

From a social planner's perspective, a live fish has a higher economic value than one caught and sold at the market. The revenues generated by the commercial fishing industry are minimal compared to the coral reef associated value for the tourism industry. Viewing fish while diving and snorkeling is more sustainable and more valuable than catching them for commercial purposes. On the other hand, catching fish for private consumption and sharing it with family and friends generates a much higher (cultural) value than that gained at the market. Therefore, recreational fishing outside marine protected areas should not be discouraged: it strengthens the cultural links between local residents and the ocean.

Recommendation 4: Prioritize potential policy interventions in an economically sound manner

Guam has limited funds with which to manage its valuable marine resources. Therefore, it is important to utilize these funds as efficiently as possible. As outlined, such a selection procedure requires an economically sound decision support tool. The most plausible tool available is an extended cost benefit analysis, which makes explicit the economic benefits gained for every dollar invested in a specific management option. During the interview process, experts in Guam mentioned a number of management options. The top three options were: i) improving the sewage discharge system, ii) reducing sediment runoff from Guam's watershed areas, and iii) increasing environmental education through curricula developed specifically to include the value of coral reefs. These three elements are also explicitly mentioned in Guam's Local Action Strategy (LAS). In future work, economic analysis could be effectively used to evaluate the feasibility of these potential measures.

7. References

Adamowicz, W., Boxall, P., Williams, M., and Louviere, J. (1998). Stated preference approaches for measuring passive use values: Choice experiments and contingent valuation. American Journal of Agricultural Economics 80, 64-75.

Adamowicz, W., Louviere, J., and Williams, M. (1994). Combining revealed and stated preference methods for valuing environmental amenities. Journal of Environmental Economics and Management 26, 271-292.

Addelman, S. (1962) Symmetrical and asymmetrical fractional factorial design plans. Technometrics, 4(1): 47-58.

Adey, W. H., and Steneck, R. S. 1985. Synergistic effects of light, wave action and geology on coral reef primary production. NOAA Symp. Ser. Underseas Res. V. I, No. 2.

Atsushi Nanami & Moritaka Nishihira. (2003). Effects of habitat connectivity on the abundance and species richness of coral reef fishes: comparison of an experimental habitat established at a rocky reef flat and at a sandy sea bottom. Environmental Biology of Fishes 68: 183-196.

Barton, D.N. (1994), "Economic Factors and Valuation of Tropical Coastal Resources", SMR-Report 14/94, Bergen, Norway, 128 pp.

Bateman,I.J., Jones, A.P., Lovett,A.A., Lake, I. & Day B.H. (2004). Applying Geographical Information Systems (GIS) to Environmental and Resource Economics. 1-21

Bennett, J. and Blamey, R. (2001). The Choice Modeling Approach to EnvironmentalValuation. Northampton, MA: Edward Elgar.

Beukering, P.J.H. van & H.S.J. Cesar (2004) Ecological Economic Modeling of Coral Reefs: Evaluating Tourist Overuse at Hanauma Bay and Algae Blooms at the Kihei Coast, Hawaii. Pacific Science, 58(2). 243-260.

Beukering, P.J.H. van & H.S.J. Cesar (2004) Economic Analysis of Marine Managed Areas in the Main Hawaiian Islands. Report for the National Oceanic and Atmospheric Administration, Coastal Ocean Program. Washington DC. p.28.

Beukering, P.J.H. van, H.S.J. Cesar, J. Dierking and S. Atkinson (2004) Recreational Survey in Selected Marine Managed Areas in the Main Hawaiian Islands. Report for the the Division of Aquatic Resources (DAR) and the Department of Business, Economic Development & Tourism (DBEDT), Honolulu, p.14

Birkeland, C., D. Rowley and R.H. Randall. (1982). Coral recruitment patterns at Guam. pp. 2: 339-344. In: Proceedings of the Fourth International Coral Reef Symposium, Manila.

Birkeland, C. (1997). Status of coral reefs in the Marianas. pp. 91-100. In: Dollar, R., and C. Birkeland. (eds.) Status of coral reefs in the Pacific. Hawaii: Sea Grant College Program, School of Ocean and Earth Science and Technology, University of Hawaii.

Blamey, R., Gordon, J., and Chapman, R. (1999). Choice modeling: Assessing the environmental values of water supply options. Australian Journal of Agricultural and Resource Economics 45(3), 337-357.

Blamey, R.K., Bennett, J.W., Louviere, J.J., Morrison, M.D., and Rolfe, J. (2000). A test of policy labels in environmental choice modeling studies. Ecological Economics 32, 269-286.

Brander, L.M., Beukering van, P. & Cesar, H.S.J. (2006). The recreational value of coral reefs: a meta-analysis. IVM Working Paper series.

Brown, M. E. and S. Brand, 1975: An Evaluation of Apra Harbor, Guam as a Typhoon Haven. NAVENVPREDRSCHFAC Technical Paper No. 19-75. Published by Naval Environmental Prediction Research Facility (now Naval Research Laboratory), Monterey, CA 93943.

Bryant, D., L. Burke, J.W. McManus, and M. Spalding, 1998: Reefs at Risk: A Map-Based Indicator of Threats to the World's Coral Reefs. World Resources Institute, Washington, DC, USA, 56 pp

Carpenter KE, Miclat RI, Corpuz VT & Albaladejo VD. (1981). The influence of substrate structure on the local abundance and diversity of Philippine reef fishes. 4th International Coral Reef Symposium 2: 497-502.

Carson, R.T., Louviere, J.J., Anderson, D.A., Arabie, P., Bunch, D.S., Hensher, D.A., Johnson, R.M., Kuhfeld, W.F., Steinberg, D., Swait, J., Timmermans, H., and Wiley, J.B. (1994). Experimental analysis of choice. Marketing Letters 5(4), 351-368.

Cesar, H.J.S. (2000). (ed) Collected Essays on the Economics of Coral Reefs. Cordio 244pp

Cesar, H.S.J. & P.J.H. van Beukering (2004) Economic valuation of the coral reefs of Hawaii , Pacific Science, 58(2), 231-242.

Cesar, H.S.J. & P.J.H. van Beukering (2004) Sustainable Financing of Marine Managed Areas: Experiences from around the World. Report for the the Division of Aquatic Resources (DAR) and the Department of Business, Economic Development & Tourism (DBEDT), Honolulu, p.23.

Cesar, H.S.J., Beukering, P.J.H. van & Pintz, S. (2002). *The Economic Value of Coral Reefs in Hawai'i.* Hawai'i Coral Reef Initiative (HCRI), University of Hawai'i, Honolulu.

Cesar, H.S.J., P.J.H. van Beukering, R. Payet & E. Grandourt (2004) Evaluation of the Socio-economic Impacts of Marine Ecosystem Degradation in the Seychelles. Report prepared for the Seychelles Marine Ecosystems Management Project of the Global Environment Fund (GEF SEYMEMP), Victoria (Seychelles), p.95.

Cesar, H.S.J., P.J.H. van Beukering, S. Pintz & J. Dierking. (2005). Economic valuation of the coral reefs of Hawaii: Pacific Science, 8-13.

Chabanet, P., H. Ralambondrainy, M. Amanieu, G. Faure & R. Galzin. (1997). Relationships between coral reef substrata and fish. Coral Reefs 16: 93-102.

Dixon, J.A. and P.B. Sherman (1990), Economics of Protected Areas: A New Look at Benefits and Costs, Island Press, Washington DC.

Dixon, J.F., L.F. Scura and T. Van't Hof. 1993. Meeting Ecological and Economic Goals: Marine Parks in the Caribbean. Ambio 22:117-125.

Done, T.J. (1995). Ecological criteria for evaluating coral reefs and their implications for managers and researchers. Coral reefs 14: 183-192.

Edinger, Evan N. and Michael J.Risk. (2000). Reef classification by coral morphology predicts coral reef conservation value. Biological Conservation 92:1-13.

Frihy, O.E., Mohamed A. El Ganaini, Walid R. El Sayed & Moheb M. Iskander. (2004). The role of fringing coral reef in beach protection of Hurghada, Gulf of Suez, Red Sea of Egypt. Ecological Engineering 22:17-25.

Galzin R, Planes S, Dufour V, Salvat B. (1994). Variation in diversity of coral reef fish between French Polynesian atolls. Coral Reefs 13: 175-180.

Gawel, M.J. (1999). Protection of marine benthic habitats in the Pacific islands: a case study of Guam. Oceanologica Acta 22, 6: 721-726.

Gladfelter W, Ogden J, Gladfelter E (1980) Similarity and diveristy among coral reef communities: a comparison between tropical western Atlantic (Virgin Islands) and tropical central Pacific (Marshall Island) patch reefs. Ecology 61 (5): 1156-1168.

Greene, W.H. (1998). Limdep (Version 7.0) [computer software]. Plainview, NY: Econometric software.

Guam Visitors' Bureau (GVB). (2001) Wedding, Dive and Waterpark Study.

Gustavson, K. 2000. Values associated with the local use of the Motengo Bay Marine Park, p. 83-96. *In* K. Gustavson, R.M. Huber and J. Rutienbeek (eds). Integrated Coastal Zone Management of Coral Reefs: decision support modeling. The International Bank for Reconstruction and Development, The World Bank, Washington D.C., USA.

Hanley, N., Wright, R.E., and Adamowicz, W. (1998b). Using choice experiments to value the environment: Design issues, current experience and future prospects. Environmental and Resource Economics 11(3-4), 413-428.

Hanley, N.,MacMillan, D., Wright, R.E., Bullock, C., Simpson, I., Parsisson, D., & Crabtree, B. (1998a). Contingent versus choice experiments: Estimating the benefits of Environmentally Sensitive Areas in Scotland. Journal of Agricultural Economics 49(1), 1-15.

Hixon MA, Beets JP. (1989). Shelter characteristics and Caribbean fish assemblages: experiments with artificial reefs. Bull Mar Sci 44: 666-680.

Hoffmann, T.C. (2002).Coral reef health and effects of socio-economic factors in Fiji and Cook Islands. Marine Pollution Bulletin 44: 1281-1293.

Kahneman, D. and Knetsch, J.L. (1992). Valuing public goods: The purchase of moral satisfaction. Journal of Environmental Economics and Management, 22, 57-70.

Kelty, R. et.al. (2004). Status of the coral reefs in Micronesia and American Samoa. Institute of Marine Science, Townsville, Queensland, Australia.

Le Quesne, K. (2000) Guam: A Market Profile. The Hotel Industry in Guam Facing Challenges as the Asia Pacific Region Moves Out of Recession. Arthur Andersen, Singapore. http://www.hotel-online.com/Trends/Andersen/2000_GuamProfile.html

Linton, Dulcie M. and George F.Warner. (2003). Biological indicators in the Caribbean coastal zone and their role in integrated coastal management. Ocean & Coastal Management 46: 261-276.

Louviere, J. J., Hensher, D.A., and Swait, J.D. (2000). Stated Choice Methods: Analysis and Applications. New York: Cambridge University Press.

Louviere, J.J., and Woodworth, G. (1983). Design and analysis of simulated consumer choice or allocation experiments: an approach based on aggregate data. Journal of Marketing Research 20, 350-367.

Luckhurst K, Luckhurst B. (1978). Analysis of the influence of substrate variables on coral reef communities. Marine Biology 49: 317-323.

McAllister, D.E. (1988) Environmental, economic, and social costs of coral reef destruction in the Philippines. Galaxea 7: 161-178.

McFadden, D. (1974). Conditional logit analysis of qualitative choice behavior. In P. Zarembka (ed.), Frontiers in Econometrics. Academic Press.

Mitchell, R.C. and Carson, R.T. (1989). Using Surveys to Value Public Goods: The Contingent Valuation Method. Baltimore, WA: Johns Hopkins University Press for Resources for the Future.

Moberg, F., and Carl Folke. (1999). Ecological goods and services of coral reef ecosystems. Ecological Economics 29: 215-233.

Morrison, M., Bennett, J., & Blamey, R. (1999). Valuing improved wetland quality using choice modeling. Water Resources Research, 35(9), 2805-2814.

Munby, Peter J., Alastair R. Harborne. (1999). Development of a systematic classification scheme of marine habitats to facilitate regional management and mapping of Caribbean coral reefs. Biological Conservation 88:155-163.

NOAA National Centers for Coastal Ocean Science (NCCOS). 2005. Atlas of the Shallow-Water Benthic Habitats of American Samoa, Guam, and the Commonwealth of the Northern

Mariana Islands. NOAA Technical Memorandum NOS NCCOS 8, Biogeography Team. Silver Spring, MD. 126 pp.

NRL (2005) Apra Harbor, The Decision to Sortie or Remain in Port. Guam Naval Research Laboratory (NRL). Monterey. http://www.nrlmry.navy.mil/port_studies/thh-nc/guam/apra/text/sect8.htm

Paulay, Gustav., Lisa Kirkendale, Gretchen Lambert & Chris Meyer. (2002). Anthropogenic Biotic Interchange in a Coral Reef Ecosystem: A case study from Guam. Pacific Science, vol. 56, no. 4:403-422.

Pearce, D.W. and Ulph, D. (1995) *A social discount rate for the United Kingdom.* Centre for Social and Economic Research on the Global Environment, University College London, London.

Phinn, S.R., A.G.Dekker, V.E.Brando, C.M.Roelfsema. (2005). Mapping water quality and substrate cover in optically complex coastal and reef waters:an integrated approach. Marine Pollution Bulletin 51:459-469.

PIFSC (2005) Guam DAWR 1980-2004 Annual Total Estimated Commercial Landings. Pacific Islands Fisheries Science Center of the National Marine Fisheries Service (NMFS) is part of the National Oceanic and Atmospheric Administration (NOAA). http://www.pifsc.noaa.gov/wpacfin/guam/dawr/Pages/gdawr_data_2.php

Porter, V., Leberer ,T., Gawel, M., Gutierrez, J., Burdick, D., Torres, V. and Lujan E. (2005). The State of Coral Reef Ecosystems of the Main Hawaiian Islands. pp. 222-269. In: J. Waddell (ed.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005. NOAA Technical Memorandum NOS NCCOS 11. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 522 pp.

Randall, R.H. (1971). Tanguisson-Tumon, Guam coral reefs before, during and after the crown-of-thorns starfish (Acanthaster) predation. M.S. Thesis for the University of Guam, Department of Biology. 119 pp.

Richmond, R.H. (1994) Effects of Major Storms on Pacific Islands. USGH Factsheet. U.S. Geological Survey, Marine and Coastal Geology Program. http://marine.usgs.gov/fact-sheets/pacificstorms/pacific.html

Richmond, R.H.. (2000) Coral Reefs – How Do They Work and What Do They Provide. Website Division of Fish and Wildlife, Commonwealth of the Northern Mariana Islands government. http://www.dfw.gov.mp/

Richmond, R.H. and G.W. Davis, (2002) Status of the coral reefs of Guam. In: Rogers, Z. *et al.*, (2002). The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2002. National Oceanic and Atmospheric Administration/National Ocean Service/National Centers for Coastal Ocean Science, Silver Spring, MD. 265 pp

Robert W. Buddemeier. Joan A. Kleypas. Richard B.Aronson (2004). Coral reefs & Global climate change: Potential contribution of climate change to stresses on coral reef ecosystems.1-44.

Roberts CM, Ormond RF. (1987). Habitat complexity and coral reef diversity and abundance on Red Sea fringing reefs. Marine Ecology 41: 1-8.

Rogers, Z. Hillis-Starr, R. Nemeth, M. Taylor, G.P. Schmahl, M.W. Miller, D.A. Gulko, J.E. Maragos, A.M. Friedlander, C.L. Hunter, R.S. Brainard, P. Craig, R.H. Richond, G. Davis, J. Starmer, M. Trianni, P. Houk, C.E. Birkeland, A. Edward, Y. Golbuu, J. Gutierrez, N. Idechong, G. Paulay, A. Tafileichig, and N. Vander Velde. (2002) The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2002.. National Oceanic and Atmospheric Administration/National Ocean Service/National Centers for Coastal Ocean Science, Silver Spring, MD.

Rosenthal, R. and M. R. DiMatteo, (2001). Meta-analysis: Recent developments in quantitative methods for literature reviews. Annual Review of Psychology, 52, 59-82.

Roxburgh, T. & J. Spurgeon. (2005). Enhancing the Role of Economic Valuation in Coral reef Management. ICRI General meeting: 1-10.

USGS (2004) Effects of Major Storms on Pacific Islands. Coastal and Marine Geology Program. U.S. Department of the Interior, U.S. Geological Survey (USGS). http://pubs.usgs.gov/fs/major-storms/index.html

Sano M, Shimizu M & Nose Y. (1984). Changes in structure of coral reef fish communities by destruction of hermatypic corals: observational and experimental views. Pacific Science 38 (1): 51-79.

Souter, David W. and Olof Linden. (2000). The health and future of coral reef systems. Ocean&Coastal Management, 43, 657-688.

Spurgeon & Roxburgh. (2004). Economic Valuation of Coral Reefs and Adjacent Habitats in American Samoa, Dept. of Commerce, Government of American Samoa: 3-1-3-23.

Spurgeon, J. (2001). Valuation of Coral reefs: The next ten years. Paper presented at "Eco-nomic Valuation and Policy Priorities for Sustainable Management of Coral reefs" an Inter-national Consultative Workshop.1-12.

UN Atlas of the Oceans. Website. http://www.oceansatlas.org/.

Underwood Hon. Robert A. (1997) The Importance Of Guam's Coral Reefs: Extension Of Re-marks. June 04, 1997, Daily Digest, E1118

Underwood Hon. Robert A. (1997) The Importance Of Guam's Coral Reefs: Extension Of Re-marks. June 04, 1997, Daily Digest, E1118

Appendix I. Overall questionnaire

I. Name Interviewer:		*IV. Name data enterer:*	
II. Date of interview:		*V. Date of data entry:*	
III. Location of interview:		*VI. ID number:*	

QUESTIONNAIRE GUAM

Introduction – Refer to the instructions in the interview protocol (Section 1 – Introduction)

I. Fish diet

1. How often does your family eat fish/seafood? We eat fish/seafood… (*check one box*)

a. Every Day	b. Every 2 days	c. Twice a week	d. Once a week	e. Every 2 weeks	f. Once a month	g. Once in 2 months	h. Never
□	□	□	□	□	□	□	□

If the answer to Q1 is 'h', never, skip to Q6

2. Please indicate the main sources of the fish/seafood you consume (percentage-wise)

Source	*Fill share (Should add up to 100%)*
1. Fish caught by myself or someone in my immediate family	
2. Fish caught by an extended family member (e.g. uncle) or friend	
3. Purchase it from the road side	
4. Purchase it a flea market	
5. Purchase it at a store/restaurant	
6. Other, specify …	

3. In general, where does the fish/seafood you consume come from (where is it caught)?

	Please fill share *(Should add up to 100%)*
1. Reef fish and other species from inside Guam's reef	
2. Fish caught outside Guam's reefs (e.g. deep water, pelagic)	
3. Imported fish/seafood from the mainland (e.g. canned from US)	
4. Imported fish/seafood from other pacific islands (e.g. Chuuk)	

4. Did your family's fish/seafood diet change over the last 10 years? (*check one box only*)

a. Eat much less fish	b. Eat some-what less fish	c. No change *(skip to Q6)*	d. Eat some-what more fish	e. Eat much more fish	f. Don't know
□	□	□	□	□	□

If the answer to Q4 is "c. no change", skip to Q6.

5. Can you indicate the 1st most, 2nd, 3rd and 4th most important reason why your family's diet of fish/seafood had changed? *(You may also check less than 4 boxes)*

	a. 1st most important	b. 2nd most important	c. 3rd most important	c. 4th most important
1. We fish less/more	□	□	□	□
2. We fish the same amount but catch less/more	□	□	□	□
3. There is more/less sharing of fish between family, friends, etc.	□	□	□	□
4. Change to other food (e.g. spam)	□	□	□	□
5. The price of fish has decreased/increased	□	□	□	□
6. Availability of certain local species changed	□	□	□	□
7. Scared of ciguatera /polluted fish	□	□	□	□
8. Preference for fish has changed (don't like fish as much)	□	□	□	□
9. Other, specify …	□	□	□	□
10. Don't know	□			

II. Recreation

6. Please indicate who in your immediate family above 8 years of age can swim? (*Check all options that apply*)

a. Respondent	b. Spouse	c. All children	d. Some children	e. No children	f. Nobody
□	□	□	□	□	□

7. How often does anyone in your household participate in each of the following activities?

	a. Every week	b. Twice a week	c. Once a month	d. Once in two month	e. ±4 times a year	f. Once a year	g. Never
1. Beach picnic/BBQ	□	□	□	□	□	□	□
2. Swimming	□	□	□	□	□	□	□
3. Kayaking/paddling	□	□	□	□	□	□	□
4. Jet skiing	□	□	□	□	□	□	□
5. Snorkelling	□	□	□	□	□	□	□
6. Scuba diving	□	□	□	□	□	□	□
7. Fishing	□	□	□	□	□	□	□
8. Body boarding/ surfing	□	□	□	□	□	□	□
9. Windsurfing/ kite-boarding	□	□	□	□	□	□	□

8. For your household, what are the 1st, 2nd, 3rd and 4th most important conditions for recreation? *(You may also tick less than 4 boxes)*

	a. 1st most important	b. 2nd most important	c. 3rd most important	c. 4th most important
1. Good public facilities (e.g. BBQ, restroom)	□	□	□	□
2. Plenty of parking space	□	□	□	□
3. Clean and wide beach	□	□	□	□
4. Clean and clear waters (unpolluted, visibility)	□	□	□	□
5. Healthy coral reefs	□	□	□	□
6. Abundant fish stock	□	□	□	□
7. Safe and calm waters	□	□	□	□
8. Proximity to home	□	□	□	□
9. Other, specify ...	□	□	□	□

III. Environmental awareness

9. In your opinion, how has the quality of the following components of the marine environment in Guam changed during your lifetime:

	a. Increased significantly	b. Increased somewhat	c. Remained stable	d. Decreased somewhat	e. Decreased significantly	f. Don't know
1. Live coral abundance	□	□	□	□	□	□
2. Fish abundance	□	□	□	□	□	□
3. Fish size	□	□	□	□	□	□
4. Fish species diversity	□	□	□	□	□	□
5. Algae growth	□	□	□	□	□	□
6. Sedimentation	□	□	□	□	□	□
7. Water pollution	□	□	□	□	□	□

If respondent did not perceive any change in the marine environment (e.g. answered 'c' or 'f' for all features in Q9), then skip to Q11.

10. What do you think are the 1st, 2nd, 3rd and 4th most important causes of the change in quality of the marine environment in Guam. *(You may also check less than 4 boxes)*

	a. 1st most important	b. 2nd most important	c. 3rd most important	c. 4th most important
1. Sedimentation due to intentionally set fires	□	□	□	□
2. Sedimentation due to poor development practices	□	□	□	□
3. Increased runoff and storm water	□	□	□	□
4. Increased pesticides/fertiliser from golf courses and hotels	□	□	□	□
5. Leakage from broken sewage pipes	□	□	□	□
6. Use of improper fishing techniques (gillnets, night scuba)	□	□	□	□
7. Too many fishermen	□	□	□	□
8. Too many jet ski's, banana boats	□	□	□	□
9. Too many divers and snorkelers	□	□	□	□
10. Other, specify ...	□	□	□	□
11. Don't know	□			

IV. Fishing

11. Does anyone in your household currently fish?

(Important Note - fishing can include any method of harvesting marine food from the sea including hook and line, spearing, netting, trapping, gathering shellfish/octopus/sea cucumber at low tide, etc).

a. Yes	b. No
□	□

If the answer to Q.11 is "Yes", ask if the person in the household who most often actively fishes can help answer the supplemental fishing survey. If the answer to Q.11 is "No", skip to section VII – Choice Experiment

(If applicable, break here to complete the supplemental fishing survey)

VII. Choice experiment

!!!!CRITICAL!!!!

Record the survey version that you are using (e.g. Green2)

12. Choice Set Version: ______________

Part I – Introduction to the Attributes

REFER TO THE INTERVIEW PROTOCOL!!!

(SECTION 2 – CHOICE EXPERIMENT)

Part II – Choice Questions

13. Record the respondent's answers to each choice question in the table below. *(Check only one box in each row).*

Choice set	Option A	Option B	Current Situation	Refused the question
Choice Set A – Common Set	ق	ق	ق	ق
Choice Set 1 –	ق	ق	ق	ق
Choice Set 2 –	ق	ق	ق	ق
Choice Set 3 –	ق	ق	ق	ق
Choice Set 4 –	ق	ق	ق	ق

If the respondent chose the "Current situation" 3 or 4 times, then ask question 14, otherwise skip to question 15.

14. In the last 4 questions, you chose the 'current situation' option at least 3 times. Please tell me why you chose it so often.

1. The people who are doing the damage should pay to protect the reefs not me	□	8. The reefs are part of our culture and traditions. We should have free and unrestricted access to them	□
2. I am not confident that the money will be used as specified…government is too corrupt	□	9. Other activities are more damaging to the reefs than the ones described in the questions…questions unfairly targeted one group	□
3. It's too late anyway. There is not much that we can do about it now.	□	10. I couldn't understand the questions…too hard to make the choices	□
4. I was not convinced that the options were realistic	□	11. The choices weren't relevant to me. Didn't describe what matters to me	□
5. The issues are more complex than these questions suggest	□	12. Other, specify…	□
6. The costs were too high	□	13. Other, specify …	□
7. Don't need another tax no matter what it is used for	□	14. Don't know/refused	□

VI. Reef Management

15. Imagine that you are the governor of Guam and that you are in the position to do something about the management of the reef fish and corals in Guam. Please indicate the 1st, 2nd, 3rd and 4th most important measures that you would take to improve the marine environment in Guam. *(You may also check less than 4 boxes)*

	a. 1st most important	b. 2nd most important	c. 3rd most important	c. 4th most important
1. Outlaw the intentional setting of fires that cause sedimentation	□	□	□	□
2. Set and enforce stricter rules on development	□	□	□	□
3. Prohibit jet-skies in areas where they can damage the reefs	□	□	□	□
4. Reduce pesticides/fertiliser use at golf courses and hotels	□	□	□	□
5. Improve the sewage system (e.g. repair/extend sewage pipe)	□	□	□	□
6. Prohibit the use of gillnets	□	□	□	□
7. Prohibit scuba spear fishing at night	□	□	□	□
8. Introduce a user fee for foreign scuba divers and snorkelers	□	□	□	□
9. Limit human use to popular sites (i.e. divers, snorkelers)	□	□	□	□
10. Increase the penalties for violators of existing laws	□	□	□	□
11. Open the marine protected areas certain periods of the year	□	□	□	□
12. Educate children and general public about marine ecosystem	□	□	□	□
13. Better enforce existing laws	□	□	□	□
14. Other, specify …	□	□	□	□
15. Nothing. Things are fine the way they are	□			
16. Don't know	□			

VI. Demographics

The remaining questions are for statistical purposes.

16. Where were you born? (*Tick only one*)

1. Guam	□	8. China	□
2. Palau	□	9. Korea	□
3. The CNMI	□	10. Japan	□
4. Yap	□	11. Hawaii	□
5. Chuuk	□	12. Mainland US	□
6. Pohnpei	□	13. Elsewhere, specify …	□
7. Kosrae	□	14. Don't know/refused	□

17. If you are not born in Guam, when did you arrive in Guam? (*fill only one cell*)

1. Please fill year of arrival in Guam	……..	*2. Born in Guam*	□

18. What is your ethnic background? I consider myself … (*If relevant, check **more** than one*)

1. Chamorro	□	8. Pohnpeian	□
2. Filipino	□	9. Palauan	□
3. Carolinian	□	10. Chinese	□
4. Korean	□	11. Japanese	□
5. Yapese	□	12. Hawaiian	□
6. Kosraen	□	13. Caucasian	□
7. Chuukese	□	14. Other, specify …	□

19. How much longer do you intend to stay in Guam?

1. Forever /All my life	□	4. Around another 5 years	□
2. Around another 25 years	□	5. Around another 1 years	□
3. Around another 10 years	□	6. Don't Know/Refused	□

20. What your profession? (*Check only one*)

1. Management, professional etc.	□	7. GUAM Government	□
2. Service & tourism	□	8. Military	□
3. Sales and office	□	9. Student	□

4. Farming, fishing forestry	☐	10. I am unemployed	☐
5. Construction, transport & maintenance	☐	11. I am retired	☐
6. US Government (non military	☐	12. Other, specify	☐

21. Please fill in the age and sex of yourself and your immediate family members.

	Sex	Age		Sex	Age
1. Respondent			6. Fourth child		
2. Spouse			7. Fifth child		
3. Oldest child			8. Sixth child		
4. Second child			9. Seventh child		
5. Third child			10. More children, fill total	#	

22. What is the highest level of education you have completed?

1. Elementary school	☐	4. Finished college (bachelor's degree)	☐
2. High school	☐	5. Advanced degree	☐
3. Some college or university	☐	6. Don't know/refused	☐

23. Please tell me about your total household (gross) income from all sources last year.

1. $5,000 or less	☐	6. $35,000 to $50,000	☐
2. $5,000 to $10,000	☐	7. $50,000 to $75,000	☐
3. $10,000 to $20,000	☐	8. Over $75,000	☐
4. $20,000 to $35,000	☐	9. Prefer not to answer	☐

24. If you have any other comments, please leave them in the box below.

If you want to be informed about the final results of this study, please leave us your contact information below.

Name (optional): ______________________

Phone (optional): ______________________

E-mail (optional): ______________________

THANK YOU VERY MUCH FOR PARTICIPATING IN OUR SURVEY!

If you have any questions or concerns about this survey, please contact Joel Sablan (Arc Environmental Services) Ph: 477-6339

Please note that your personal information will not be linked to your survey responses. Published information will be in summary form only. We will not use your contact information for purposes other than contacting you about the results of the survey. In addition, we will not trade, sell or otherwise provide your personal information to any other party.

Appendix II. Fishery questionnaire

Guam Coral Reef Household Survey – Supplement, Fishing survey

To be filled out by interviewer:

I. Name Interviewer:		*IV. Name data enterer:*	
II. Date of interview:		*V. Date of data entry:*	
III. Location of interview:		*VI. ID number:*	

Start here…

Important Note – for this survey, fishing refers to any form of harvesting marine food from the sea including hook and line, spearing, netting, trapping, gathering shellfish/octopus/sea cucumber at low tide, etc.

1. How often do you fish? Once every … (*check only one box*)

a. Day	b. 2 or 3 days	c. Week	d. 2 weeks	e. Month	f. 2 Months	g. 6 Months	h. Year	i. Never
☐	☐	☐	☐	☐	☐	☐	☐	☐

2. On average, how much time is spent actively fishing per trip? (*check only one box*)

a. 0-2 hours	b. 2-4 hours	c. 4-6 hours	d. 6-8 hours	e. 8-12 hours	f. 12-18 hours	g. >18 hours
☐	☐	☐	☐	☐	☐	☐

3. Can you indicate 1st most, 2nd, 3rd and 4th most important reasons why you go fishing?

(*You may also check less than 4 boxes*)	a. 1st most important	b. 2nd most important	c. 3rd most important	c. 4th most important
1. I really enjoy fishing	☐	☐	☐	☐
2. I really need the fish to feed my family	☐	☐	☐	☐
3. Giving catch to family, friends, and others strengthens social bonds; sharing is part of our culture.	☐	☐	☐	☐
4. I really need the money from the fish I sell	☐	☐	☐	☐
5. Tradition: My family has always fished. Fishing is my life!	☐	☐	☐	☐
6. Fishing strengthens the bond with my fellow fishermen	☐	☐	☐	☐
7. Fishing strengthens the bond with my children/family	☐	☐	☐	☐
8. I go fishing especially for mañahak, ti'ao, and e'e during seasonal runs	☐	☐	☐	☐
9. I go fishing to catch fish for fiestas/parties	☐	☐	☐	☐
10. Other, specify …	☐	☐	☐	☐
11. Don't know	☐	☐	☐	☐

4. How many years have you been fishing on Guam?

a. less than 2 years	b. 2 to 5 years	c. 6 to 9 years	d. 10 years or more
□	□	□	□

Answer Q5 only if you have been fishing on Guam for 10 years or more.

5. 10 years ago, how often did you go fishing on Guam? Once every… (*check only one box*)

a. Day	b. 2 or 3 days	c. Week	d. 2 weeks	e. Month	f. 2 Months	g. 6 Months	h. Year	i. Never
□	□	□	□	□	□	□	□	□

Answer Q6 only if your fishing behavior has changed over time (e.g. you fish more or less often)

6. Why has your fishing behaviour changed over time? Please indicate the 1st most, 2nd, 3rd and 4th most important reasons. *(You may also check less than 4 boxes)*

	a. 1st most important	b. 2nd most important	c. 3rd most important	c. 4th most important
1. Because I grew older	□	□	□	□
2. Because I have less/more time than before to go fishing	□	□	□	□
3. Because the need for fish for my family has changed	□	□	□	□
4. Because the need for additional income from fishing has changed	□	□	□	□
5. Because fish availability has changed (quantity and size)	□	□	□	□
6. Because the cost of fishing has changed (fuel, gear, etc)	□	□	□	□
7. Because my family changed their fish diet	□	□	□	□
8. Because I only started fishing recently	□	□	□	□
9. Other, specify …	□	□	□	□
10. Don't know	□			

7. Please indicate your average monthly expenses on fishing related items.

Cost category	*Please fill amount (US$/month)*
1. Fuel & oil	
2. Ice	
3. Bait (i.e. fresh)	
4. Fishing Equipment (e.g. nets, lures, lines, and hooks)	
5. Scuba tank fills	
6. Other, specify …	
7. Don't know	□

8. What are the 1st most, 2nd, 3rd and 4th most important fishing techniques that you use? *(You may also check less than 4 boxes)*

	a. 1st most important	b. 2nd most important	c. 3rd most important	c. 4th most important
1. Bottom: hook & line (less than 100ft)	□	□	□	□
2. Bottom: hook & line (more than 100ft)	□	□	□	□
3. Trolling	□	□	□	□
4. Cast net (Talaya)	□	□	□	□
5. Drag and surround net (Chenchulu)	□	□	□	□
6. Gill net (Tekken)	□	□	□	□
7. Snorkel spear fishing during daytime	□	□	□	□
8. Snorkel spear fishing at night	□	□	□	□
9. Scuba spear fishing during the day	□	□	□	□
10. Scuba spear fishing at night	□	□	□	□
11. Foraging the reef (shell, crabs, etc)	□	□	□	□
12. Trapping (octopus, crabs, etc.)	□	□	□	□
13. Other techniques, specify …	□	□	□	□

9. How often do you encounter people using illegal fishing practices (for example, dynamite, chlorine, fishing in marine reserves, etc.) or find evidence that people have recently used illegal practices in an area? … (*check one box only*)

a. Regularly	b. Occasionally	c. Rarely	d. Never
□	□	□	□

10. On average, how much fish/seafood does you catch on a monthly basis?

Please fill average amount:	……	*Pounds per month*

11. What percentage of your average monthly catch is made of each of the following types of fish? (Distribute catch percentage-wise across the different types of fish)

Type of catch	*Percentage (must add up to 100%)*
1. Reef fish	
2. Reef invertebrates such as octopus, shellfish, crab, etc)	
3. Shallow bottom fish (less than 100 ft)	
4. Deep bottom fish (more than 100 ft)	
5. Pelagic fish	
6. Other, specify….	

12. Several options for distributing your household's catch are listed below. Please indicate how your catch is normally divided up (i.e. percentage-wise).

Options for distributions	*Fill share (must add up to 100%)*
1. Consumption by my immediate family	
2. Distribute it among my extended family and friends	
3. Sell it to fish shop or Co-op	
4. Sell it elsewhere	
5. Other, specify …	

13. On average, how much cash income does your household receive on a monthly basis from selling fish?

Please fill average amount:	……....	*US$ per month*

14. Do you own a boat? … (*check one box only*)

a. Unmotorized	b. Motorized (<15hp)	c. Motorized (>15hp)	d. No boat
□	□	□	□

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Pacific Islands Fish and Wildlife Office
300 Ala Moana Boulevard, Room 3-122, Box 50088
Honolulu, Hawaii 96850

In Reply Refer To:
2007-FA-0204

SEP 25 2007

MEMORANDUM

To: Regional Environmental Officer
Oakland, California
(Attn: Patricia Port)

From: Field Supervisor, Pacific Islands Fish and Wildlife Office
Honolulu, Hawaii

Subject: Draft Environmental Impact Statement (DEIS) for the Master Plan for Deep-draft Wharf and Fill Improvements at Apra Harbor (ER 07/714)

Attached for the Regional Environmental Officer's review are the Pacific Islands Fish and Wildlife Office's comments on the referenced action. These comments are provided for your use in preparing the Department's comments to the Department of the Navy by October 1, 2007.

In Reply Refer To:
ER 07/714

Mr. James Hatashima
U.S. Army Corps of Engineers, Honolulu District
Civil and Public Works Branch
Rm. 309, Bldg. 230
Fort Shafter, Hawaii 96858-5440

Dear Mr. Hatashima:

The Department of the Interior (Department) has reviewed the Draft Environmental Impact Statement (DEIS) for the Master Plan for Deep-draft Wharf and Fill Improvements at Apra Harbor, Guam. In addition, we have received comments from the Pacific Islands Fish and Wildlife Office (PIFWO) on the DEIS, which was received by them on August 17, 2007. The following comments are provided in accordance with the National Environmental Policy Act of 1969 [42 U.S.C. 4321 *et seq.*; 83 Stat. 852] (NEPA); and other authorities mandating Federal oversight of environmental resources including the Fish and Wildlife Coordination Act of 1934 [16 U.S.C. 661 *et seq.*; 48 Stat. 401], as amended (FWCA); the Federal Clean Water Act [33 U.S.C. 1251 *et seq.*; 62 stat. 1155], as amended (CWA); and the Endangered Species Act of 1973 [16 U.S.C. 1531 *et seq.*; 87 Stat. 884], as amended (ESA).

The proposed action would upgrade the civilian commercial port of the Territory of Guam by constructing a 1,500 linear foot deep-draft wharf and reclaiming 17 acres in three shallow, coral reef embayments for use as additional cargo container storage area. These harbor improvements would accommodate Post-Panamax cargo vessels, cruise ships, and also provide contingency berthing facilities for U.S. Navy military vessels, including Nimitz Class aircraft carriers.

While the DEIS has included a detailed impacts analysis and a commitment to scale compensatory mitigation to replace projected resource loses via a Habitat Equivalency Analysis (HEA), it falls short of being a comprehensive and adequate decision-making document. Four significant issues remain unresolved, including: 1) the lack of viable compensatory mitigation measures; 2) the lack of an adequate CWA Section 404(b)(1) analysis for the disposal of dredge and fill material; 3) the proposed non-water dependent filling of two nesting beaches for federally protected sea turtles; and 4) the extremely distant timeline for project implementation. In addition to the general comments provided below, we have enclosed specific comments on the DEIS in Appendix 1 to this letter.

The DEIS does not appear to meet Army Corps of Engineers requirements for a 404(b)(1) analysis[1]. Coral reefs are considered a type of special aquatic site and proposed actions that will result in dredging or filling such sites are required to be "water dependent" in order for the

[1]CFR 40 Part 230 Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material. Available online at http://www.usace.army.mil/cw/cecwo/reg/40cfr230.pdf.

proposed action to occur. For proposed actions that are not inherently water dependent, "...practicable alternatives that do not involve special aquatic sites are presumed to be available. unless clearly demonstrated otherwise."[2] Additionally, "...all practicable alternatives to the proposed discharge, which do not involve a discharge into a special aquatic site are presumed to have less adverse impact on the aquatic ecosystem, unless clearly demonstrated otherwise."[3] We believe that the filling of over 16 acres of coral reef habitat for the installation of backland container yards does not meet the necessary "water dependent" requirement and that practicable alternatives with lower associated environmental impacts have not been fully investigated in the DEIS. Alternatives that considered use of container storage areas outside of Apra Harbor appear to have been removed from the analysis solely because of their distance to the proposed wharf, while the use of non-water dependent backland cargo container storage areas remained part of the analysis. Additionally, failure to fully consider 404(b)(1) guidelines in this planning document, and instead delay consideration of these requirements until application of a CWA Section 404 permit, will produce a planning document that does not fully disclose the necessary information with which to make sound environmental decisions.[4] We believe that without a valid 404(b)(1) analysis of alternatives, this DEIS cannot be finalized. We recommend that an appropriate 404(b)(1) analysis be conducted, and, as appropriate, all viable alternatives to reclaiming over 16 acres of coral reef for backland cargo container storage be rigorously analyzed in the DEIS.

The proposed harbor improvements will cause the permanent loss of over 24 acres of coral reef and result in adverse impacts to additional acreage as result of construction-related and future operational activities. Two compensatory mitigation projects have been proposed in the DEIS: Fish Aggregation Devices (FADs) and coral transplantations. Neither proposed mitigative action has been scaled using Habitat Equivalency Analysis (HEA), and it is our position that neither are viable projects that will compensate for the potential permanent loss of the coral reef ecological functions that will result from the proposed harbor improvements.

FADs are primarily fishery management tools and their value in coral reef restoration is questionable, primarily because they aggregate existing pelagic fish stocks, rather than enhance overall production. The ecological services anticipated to be lost extend beyond those that can be replaced by FADs, and whatever value they may have cannot be scaled to compensate for coral reef losses. Additionally, evidence exists that FADs may contribute to the over-fishing of some species[5] and may result in the long-term loss of ecological function. Coral transplantation has had mixed success, particularly in the Pacific[6], often resulting in poor transplant survival and

[2]CFR 40 Part 230 Section 404(b)(1). Section 230.10(a)(3)
[3]CFR 40 Part 230 Section 404(b)(1). Section 230.10(a)(3)
[4]CFR 40 Part 230 Section 404(b)(1). Section 230.10 (a)(4) states that a 404(b) analysis of alternative must be included in NEPA documentation, either the Final EIS or a Supplemental EIS.
[5]Don Bromhead, D., J. Foster, R. Attard, J. Findlay, J. Kalish. 2003. A Review of the impact of fish aggregating devices (FADs) on tuna fisheries. Final Report to Fisheries Resources Research Fund, Dept. of Agriculture, Fisheries & Forestry, Canberra, Australia. 121 pp. Available online at: http://affashop.gov.au/product.asp?prodid=12777.
[6]Bentivoglio, A. 2003. Final Report: Compensatory Mitigation for Coral Reef Impacts in the Pacific Islands. Pacific Islands Fish and Wildlife Office. 36 pp. Available online at: http://www.fws.gov/pacificislands/worg/pcrmreport.pdf.

little ecological benefit. Additionally, transplantation of coral to already impacted reefs will do little to improve reef health without concurrent reductions of relevant existing ecological stressors and, therefore, is expected to do little to offset losses. In a review of compensatory mitigation projects on Caribbean coral reefs, coral transplantation and mooring buoys were specifically identified as inappropriate and inadequate for mitigating permanent dredging impacts to coral reefs[7]. We acknowledge that efforts to transplant corals that will otherwise be lost has value, but it cannot be scaled appropriately, and, therefore, will not replace lost the ecological functions and serve as valid compensatory mitigation. We support National Research Council (NRC) guidelines[8] that recommend a watershed approach be used when developing and implementing mitigative actions.

A viable mitigation plan should be developed with the direct input of Federal and territorial resource agencies and it should be included in the Final EIS and Record of Decision. The PIFWO has worked with other Federal and Territorial agencies to develop mitigation plans for a similar project in Apra Harbor, and they can provide valuable input into development of appropriate mitigative actions for the proposed project. PIFWO's continued early involvement in the planning process is critical to ensure that mitigative actions are initiated either before or, at latest, concurrent with the start of the proposed project, as recommended by the NRC[9] and required as a condition of issuance of a CWA Section 404 permit.

While the Fish and Wildlife Service shares jurisdiction with National Marine Fisheries Service (NMFS) over federally threatened green (*Chelonia mydas*) and endangered hawksbill (*Eretmochelys imbricata*) sea turtles, we have sole jurisdiction over these species when they are on shore. Green sea turtles have experienced severe population depletion due to nesting habitat destruction[10] and over-exploitation of eggs and individuals for food, oil and other products[11]. In particular, human development has had an increasingly serious impact on green sea turtle nesting beaches.

Based on information from the Guam Division of Aquatic and Wildlife Resources, sea turtles are commonly observed in the project area, and are known to nest within the proposed project site in at least two different locations. The DEIS does not contain information on the most recently documented nesting location, and we recommend that this information be included. Both of these documented turtle nesting beaches would be destroyed by the proposed action. Additionally, we find the determination of no adverse impact to this species to be unsupported.

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[7]U.S. Fish and Wildlife Service. 2004. Final Report: Investigation sof Mitigation for Coral Reef Impacts in the U.S. Atlantic: South Florida and the Carribean. USFWS Southeast Regional Office. 97 pp. Available online at: http://www.coralreef.gov/library/pdf/Atl%20write-up.pdf.

[8]National Resource Council. 2001 Compensating for Wetland Losses Under the Clean Water Act. National Academy Press, 2101 Constitution Ave., NW, Box 285, Washington, D.C. 267 pp.

[9]National Resource Council, *op. cit.*

[10]Amerson, A.B. 1971. The natural history of French Frigate Shoals, Northwestern Hawaiian Islands. Atoll Res. Bull. 150: 1–120.

[11]Balazs, G.H. and M. Chaloupka. 2004. Thirty-year recovery trend in the once depleted Hawaiian green sea turtle stock. Biol. Conserv. 117: 491–498.

The status of turtle nesting on Guam is currently unclear, but may be improving slightly; however, data at this time are uncertain due to recent changes in survey methodologies. Regardless, the proposed action will have adverse effects on known green sea turtle nesting locations. Therefore, we recommend contacting our office regarding initiation of section 7 consultation.

According to the DEIS, proposed project construction is not anticipated to begin until 2021 or later. Environmental documents are generally considered to be accurate for approximately five years after they have been written. Therefore, this DEIS appears to be extremely premature. Nevertheless, if a Final EIS and Record of Decision for the proposed action are to be prepared, the mitigation recommendations of a Final FWCA Report from the Department should be incorporated into the analyses and decisions included in those documents. If project construction will not be initiated until 2021, a new or supplemental EIS, including a new or supplemental FWCA Report from the Department, will be required prior to the start of any work.

We appreciate the opportunity to comment on this DEIS. If you have questions regarding these comments please contact PIFWO Fish and Wildlife Biologist Dwayne Minton at 808-792-9445.

Sincerely,

Patricia Sanderson Port

Enclosure

cc:
DOI-OEPC, Washington D.C.
USFWS, Region 1, Portland
EPA Region 9, Honolulu
NMFS – PIRO, Honolulu
DAWR, Guam
CRMP, Guam
GEPA, Guam

APPENDIX 1

Specific Comments on the DEIS for the Master Plan for Deep-draft Wharf and Fill Improvements at Apra Harbor, Guam

Section 3.6.4 Environmental Consequences (page 97). We commend the plan to shield lights to reduce unnecessary light pollution. In addition to having impacts on nearby communities, night time lighting can adversely affect sea turtles and birds protected under the Migratory Bird Treaty Act, which have not been considered in the DEIS. We recommend that lights be shielded to reduce impacts to these species. If assistance with developing appropriate light shielding specifications is needed, we encourage you to contact our office for assistance.

Section 3.6.4 Proposed and Potential Mitigation Measures (page 99). Outhouse Beach is an important location used for introductory level SCUBA diving instruction. The Pacific Association of Dive Industry estimates that over 5,000 entry level certifications were issued in Guam in 2004[12], and it has long been recognized that Guam has few coral sites appropriate to conducting this type of activity. The displacement of divers into other locations will result in increased adverse impacts at those locations. The DEIS needs to better examine the potential indirect impacts to coral reefs resulting from the displacement of introductory levels divers into other locations. We recommend that the DEIS include an estimate of the number of divers displaced by the proposed action and include a discussion of appropriate alternate sites to which these divers may move. Using the available literature on SCUBA diver-related damage, we also recommend that the DEIS assess the potential impact of these displaced divers on these alternate locations and include this impact in the HEA and compensatory mitigation plan.

Section 3.6.4 Proposed and Potential Mitigation Measures (page 99). Tumon Bay has been proposed as an alternative to Outhouse Beach as a potential substitute diving location. Tumon Bay is a Territorial Marine Protected Area (MPS), and, while diving is a permitted action, commercial operations may be required to obtain a permit to operate and conduct introductory-level training courses (see Guam Public Law 27-87). Additionally, increasing numbers of divers will increase the damage to Tumon Bay's coral reefs, a result that is inconsistent with the MPA. We recommend that Tumon Bay be removed as an example of an alternative site at which to conduct introductory SCUBA diving training.

Section 3.11.4 Environmental Consequences (page 131). It is unclear why the effects of typhoon on contaminated sediments would only occur under the No Action alternative. The proposed dredging operations will not remove all contaminated sediments from Apra Harbor or deepen all parts of the harbor. Typhoon generated waves would still have the potential to stir harbor sediments in all proposed alternatives. If this impact is truly associated with only the No Action alternative, we recommend that the discussion of this potential impact be clarified. Otherwise, we recommend that the proposed impact be discussed for all alternatives.

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[12]Porter, V., T. Leberer, M. Gawel, J. Guiterrez, D. Burdick, V. Torres, and E. Lujan. 2005. The state of coral ecosystems of Guam. In *Status of Coral Reef Ecosystems of the United States and the Pacific Freely Associated States 2005* (J. Waddell, ed.). NOAA Technical Memorandum NOS NCCOS 11. NOA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Springs, MD. Pp. 442-87.

Section 3.11.4.2 Construction Impacts (page 135). We commend the inclusion of the sediment modeling in the DEIS. We are concerned, however, that the analysis treats the environmental impact from different sediment size classes as equal. Fine sediments present a greater risk to coral reef organisms than coarser sediments and can have adverse impacts at concentrations as low as 4-5 mg/cm^2 in as short as 1 hour of exposure[13]. The sediment threshold used for the impact assessment (37 mg/cm^2) was derived from general sediment studies and may not be best value to assess impacts from the fine, nutrient rich sediments of Apra Harbor. We recommend that this threshold for sediment impacts either be lowered to or include a secondary impact threshold of 5 mg/cm^2 when assessing the potential impacts expected to result from the proposed dredging operations.

Section 3.11.4.3 Operational Related Impactys (page 137). The DEIS discusses sediment impacts associated with the maneuvering of Post-Panamax vessels. It is unclear if this chronic impact to adjacent reefs has been considered in the impact assessment or for proposed compensatory mitigation. This impact will occur as a result of the proposed project and must be included in the compensatory mitigation plan. We recommend the DEIS consider chronic sediment suspension resulting from vessel maneuvering by estimated the spatial and temporal boundaries and the resulting environmental damage of this potential impact.

Section 3.11.5 Proposed and Potential Mitigation Measures (page 139). We commend the inclusion of the Best Management Practices (BMPs). While stated elsewhere in the DEIS, the provision to halt dredging 10 days pre- and post-coral spawning is not included in list of BMPs. We recommend that this BMP be provided to make this list comprehensive.

Section 3.12.2 Terrestrial Environment (page 150). Sasa Bay Wetlands are a Territorial MPA. We recommend the DEIS be changed to reflect the protected status of the Sasa Bay wetlands.

Section 3.12.3.1 General (page 153) and Appendix A. The color key for water depths in Figure 3-11 appears to be incorrect. We recommend that Figure 3-11 be reviewed and corrected if necessary.

Section 3.12.3.2 Coral Reefs (page 162 through 163). While it is doubtful that the conclusions will change, the comparison of species numbers between the different reef zones should be conducted using mean species per site and not total species observed in each zone. The number of transects surveyed in the reef flat was lower than in other coral reef zones. With the reduced survey effort, a lower total number of colonies and species observed would be expected. We recommend that comparisons of colony numbers and species observed be conducted using standardized values.

Section 3.12.3.1 General (page 154 through 168). Deep sand was not surveyed as part of the Fish and Wildlife Coordination Act Report. Including this reef zone in Table 3-21 through 3-25 creates the impression that no species are present in this zone and is misleading. We recommend that the column for "Deep Sand" be removed from Tables 3-21 through 3-25.

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[13]Fabricius, K. E. and E. Wolanski. 2000. Rapid smothering of coral reef organisms by muddy marine snow. *Estuar. Coast. Shelf Sci.* 50: 115-20.

Section 3.12.3.1. General (pages 163 and 169). Tables 3-24 and 3-26 contain erroneous total values for number of species. Many species occur at multiple sites and this value is not additive within the table (*e.g.*, Table 3-23 shows only 24 coral species, but Table 3-24 shows 104 total species). We recommend that the total values for the number of species be corrected in both tables.

Section 3.12.3.3 Reef Fish (page 171). The snail *Nerita polita* is an algal grazer[14]. We recommend that Table 3-28 be corrected and that appropriate changes be made to the discussion of diets.

Section 3.12.3.3 Reef Fish (page 171). The DEIS accurately points out that comparisons between fish landings at the two DAWR sites may be misleading. Without having data on fisherman effort and catch per unit effort (CPUE), it is difficult to get an accurate picture of the fisheries at the two sites. If the data is available, we recommend including estimates of fisherman effort and CPUE in the DEIS.

Section 3.12.6.3 Potential Compensatory Mitigation (page 188). We support the implementation of BMPs to reduce the potential impacts to federal trust species as a result of the proposed action. The suspension of dredging activities around the summer coral spawning events is commended. However, in Guam corals spawn during the months of June, July and August[15], and we recommend that dredging operations be curtailed during all three months.

Section 3.13.2 Affected Environment (page 192). The text description of the location of the sea turtle nest within the project area does not agree with the location on Figure 3-18. Additionally, a second turtle nest was documented by DAWR in the summer of 2007. We recommend that both the text and the figure be corrected to reflect the actual location of both documented sea turtle nests.

Section 3.15 Noise (page 210 through 221). It is relevant to include a discussion of underwater noise in the DEIS. The dredging and increased shipping activity that will result from the proposed project will alter the underwater sonic landscape of Apra Harbor, potentially impacting marine life and people. Apra Harbor is a popular recreational location, especially for divers and increases in underwater noise may adversely impact this industry. Underwater noise may also adversely impact threatened or endangered sea turtles and other trust species. We recommend that an analysis of underwater noise be included in the DEIS.

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[14]Kay, E.A. 1979. Hawaii Marine Shells. Reef and Shore Fauna of Hawaii, Section 4: Mollusca. Bishop Museum Press, Honolulu HI. 653 pp.
[15]Richmond, R. H. and C. L Hunter. 1990. Reproduction and recruitment of corals: comparisons among the Caribbean, the tropical Pacific and the Red Sea. *Mar. Ecol. Prog. Ser.* 60: 185-203.