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Policy Options

Valuing mangrove resources in Kosrae, Micronesia

ROSAMOND NAYLOR AND MARK DREW*
Center for Environmental Science and Policy,
Institute for International Studies, Encina Hall, E405
Stanford University, Stanford, CA. 94305-6055 USA
Tel: 650–723-5697, Fax: 650–725-1992,
Email: roz@leland.stanford.edu

ABSTRACT Mangrove ecosystems provide a wide range of market and non-market benefits to coastal communities in the developing world, yet they remain undervalued and overexploited in most regions where they are found. This paper analyzes the use and value of mangroves in Kosrae, Micronesia, where the population is largely dependent on the swamps for fuelwood and other ecosystem services, such as erosion control, storm protection, and nutrient flows to shoreline fisheries. The results show that mangroves on the island are worth between $666 thousand and $1 million per year (1996 prices) based on the net value of marketable products alone. In addition, household survey data suggest that the local people are willing to pay between $1 million and $1.26 million per year to protect and use mangrove swamps indefinitely. The results thus indicate that the population places some premium on the existence and indirect ecosystem services of mangroves, over and above the direct use values. Moreover, respondents generally favored—and were willing to pay more for—a tax system designed to manage and preserve the mangroves' direct and indirect services over a permit system focused only the allocation of direct use over time. Valuation analyses using revealed preference and contingent valuation methods lead to additional conclusions regarding the distribution of benefits, with poor households deriving more direct benefits from—but willing to pay less to protect—mangrove ecosystems.

Key words: mangroves, ecosystem services, contingent valuation, income distribution, public goods.

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Mangrove forests play a critical role in the ecology and economics of tropical coastline communities, yet they have been grossly undervalued—and hence overexploited—in most regions where they are found. About one-half of the world's mangroves have already been destroyed or severely degraded by human activities, such as logging, road construction, drainage operations, hydroelectric development, or conversion to agriculture or aquaculture (World Resources Institute, 1996). While the importance of forested wetlands to terrestrial and marine ecosystems has become widely recognized in several industrialized countries, where policies to mitigate damages are now in place, mangroves continue to be destroyed in many developing countries. Continued damage to mangrove ecosystems has important implications for productivity as well as equity, since a disproportionately large share of the world's poor lives in coastal villages of the developing world.

In this paper, we explore the perception and valuation of mangrove ecosystem services among village communities in Kosrae—a remote island in the Federated States of Micronesia (FSM) whose population is largely dependent on mangroves for subsistence and fuel. The goals of the paper are threefold: to describe the importance of mangroves to the Kosraean economy and environment; to assess local people's knowledge of mangrove ecosystem services; and to analyze the values that people of Kosrae assign to mangroves, using contingent valuation techniques that capture the value of both market and non-market benefits. There have been no contingent valuation or other subjective valuation studies to our knowledge that focus specifically on mangrove resources in the developing world, yet understanding values from a local perspective is critical for designing and implementing public policies to protect mangrove ecosystems in the future.

Kosrae is a particularly interesting site to study for several reasons. Foremost, the island has a relatively large intact stand of mangroves, covering 1,562 hectares and occupying roughly two-thirds of the shoreline (Whitesell *et al.*, 1986). Pressures on these mangroves are increasingly severe, with a human population of roughly 7,500 growing at a natural rate of 3 per cent annually, and with over one-third of the households using wood from mangroves as the primary source of cooking fuel (Office of Planning and Statistics, 1996). Moreover, cooking with mangrove wood—an inferior source of fuel for daily use—could increase dramatically in the future if there are significant changes in income and employment patterns. Over 55 per cent of the formal work force is currently employed by the government, which is financially dependent on the United States through the Compact of Free Association. The Compact officially ends in 2001, and its renewal is in question (FSM Economic Summit, 1995). If it is terminated or only partially extended, many government jobs could be eliminated. Under such conditions, real incomes would fall, and the demand for mangrove wood as a principal fuel source would almost surely increase.

At the other end of the spectrum, one-fifth of Kosrae's labor force still pursues a subsistence livelihood or is engaged informally in fishing or agricultural activities for the market (Office of Planning and Statistics, 1996). This group is largely dependent on mangroves for survival and is

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thus presumed to have a relatively high level of knowledge about the ecosystem services that mangroves provide. Nonetheless, people in this group are also more detached from the monetary economy and tend to have lower net incomes than those in the formal sector. As a result, it is unclear *a priori* whether the subjective value that these people might assign to mangrove resources would be very low or extremely high. In this analysis, we evaluate the relationship between knowledge, stated values, and use of the resources under economic conditions in which subsistence and informal activities remain significant.

Our study differs from most contingent valuation analyses in the literature that have focused predominantly on developed countries; these studies generally have sought to quantify the values of non-market amenities (such as clean air) or existence values of resources for cost–benefit assessments and legal proceedings (Cropper and Oates, 1992; Portney, 1991).[1] Such valuation exercises have been relatively unimportant for developing countries, where the immediate needs of food, drinking water, health services, and education take priority over improved air quality and the protection of inaccessible resources. Direct use of resources, such as mangrove forests and fisheries, plays a more fundamental role in the daily existence of poor people throughout the developing world. Given the lack of well-defined property rights for resources in many poor regions, our conjecture is that perceptions of resource value are important in determining the evolution of both informal and formal institutions that govern resource use and depletion over time (Dasgupta, 1993, 1996; Dasgupta and Maler, 1994).

Economic and ecological role of mangroves

Mangroves occupy an estimated 15 million hectares globally and line one-quarter of the world's tropical coastlines (World Resources Institute, 1996). They are most abundant and diverse in tropical delta regions—where the accumulation of alluvial sediments provides a substrate for mangrove colonization—and along sheltered shores protected by large land masses. Significant stands of mangroves are also found along small island shores of the tropics, and to a much lesser extent along some temperate shorelines. Species diversity is highest in Southeast Asia, where approximately two-thirds of all mangrove species are found. Much less diversity exists in Africa and the Americas, and there is a rapid decrease in the number of mangrove species with increasing latitude (Saenger, Hegerl and Davie, 1983; Tomlinson, 1986).

On the island of Kosrae, located at 5°–20° north of the equator in the Eastern Caroline Islands group (figure 1), mangrove swamps cover 15 per cent of the land mass. These swamps contain an intermediate level of floral diversity by global standards, with approximately 31 species of vascular plants and 7 species of mangrove trees (Hosokawa, Tagawa and Chapman, 1977; Whitesell *et al.*, 1986; Devoe and Cole, in press). An additional 70 per cent of the island's land area is comprised of tropical forests over

[1] Existence value is defined as the value to a person of just knowing that a particular ecosystem or resource exists, regardless of any personal use now or in the future (Goulder and Kennedy, 1997).

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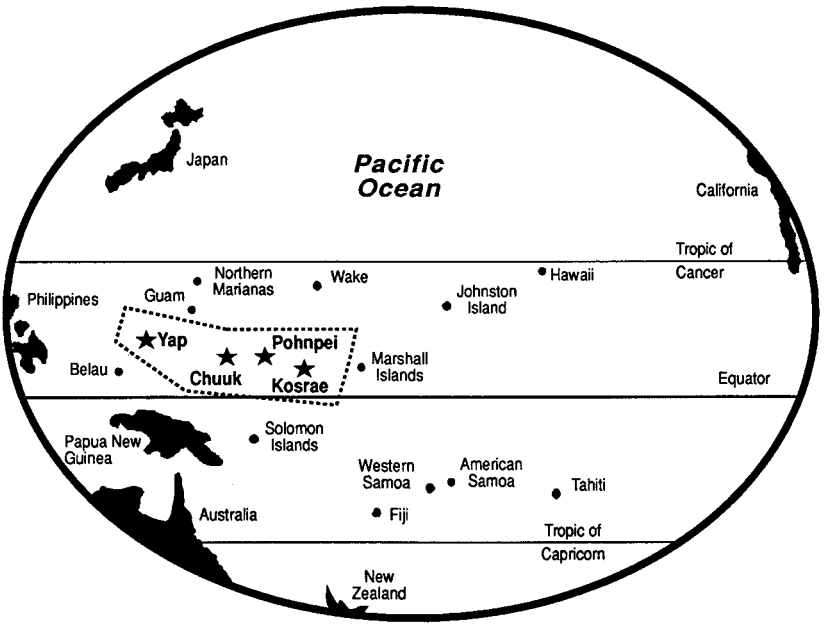


Figure 1

extremely mountainous terrain, leaving only a narrow strip of coastal plain between the mountains and sea for human settlements. The island is surrounded by a fringing reef, which provides a large lagoon with abundant fishing.

Mangrove swamps in Kosrae—like those throughout the tropics—provide a wide range of ecological services that benefit local communities directly and indirectly. Mangroves absorb and recycle nutrients from human settlements; they buffer rivers and marine systems from non-point source pollution associated with agricultural chemicals, livestock waste, and refuse; and they maintain the integrity of coastal settlements through erosion control, flood control, and storm protection (Saenger *et al*., 1983; Ewel, Twilley, and Ong, in press). In addition, they serve as nursery areas and habitats for commercially valuable shrimp and prawns, and for locally consumed fish species and mangrove crabs. Through the export of nutrients to coastal ecosystems, they also support off-shore fisheries. The full suite of ecosystem processes related to mangroves is outlined in figure 2.

One of the most important direct services of mangroves to local communities in the tropics comes from the wood itself, which is used primarily for fuelwood and timber. On the island of Kosrae, several species of mangrove trees are harvested, including *Rhizophora apiculata, Rhizophora mucronata, Bruguiera gymnorrhiza, Nypa fruticans, Sonneratia alba, Xylocarpus granatum,* and *Lumnitzera littorea. Rhizophora apiculata* and *Bruguiera gymnorrhiza* are the primary species extracted for fuelwood. Both species are harvested inefficiently; preliminary evidence by Tara (1997) indicates that

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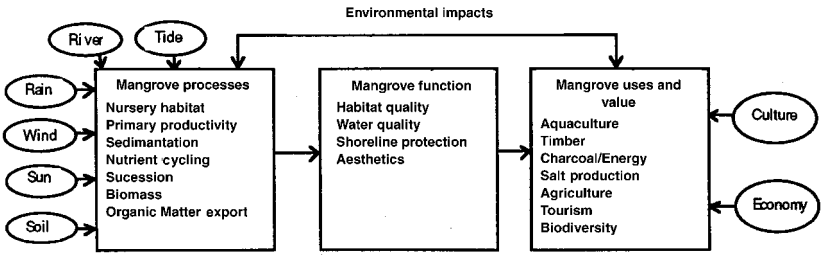


Figure 2: *Ecosystem Processes Related to Mangroves*
Source: adapted from Twilley *et al.* (1993)

only about 40 per cent of the volume of the trees that are cut is actually taken from the forest. As a result, the damage to mangrove forests from fuelwood collection tends to be quite high.

Furthermore, the value of fuelwood, timber, and seafood extracted from the swamps is just a fraction of the total value of indirect and direct services that mangroves provide to the Kosraean population. Many of these services, such as erosion control, storm protection, flood control, and water quality maintenance, are not valued in the market at all. In order to gain some insight into the Kosraeans' knowledge, use, and perceived values of these non-market services, we conducted a household survey in 1996. The survey, described below, was designed to capture the population's recognition of both the direct use values and indirect ecosystem services associated with mangroves on the island.

Description of the survey

In the survey, we elicited information about the population's knowledge of individual services, such as erosion control and water quality maintenance; their direct and indirect use of mangroves; and their quantitative assessment of what mangroves are worth based on contingent valuation techniques.[2] Households were selected randomly within each of the five municipalities (figure 3): Lelu, Malem, Utwe, Tafunsak, and Walung.[3] The total sample of 58 households was not stratified by age, gender, or income.

The first section of the survey contained questions on the socioeconomic characteristics of the respondents, such as household size, gender, age, and education. As a proxy for income, which is notoriously difficult to elicit directly in household surveys, we asked about the employment activities of the adults in each household. Employment was categorized by govern-

[2] For information about the survey, or to obtain a copy of the survey, please write to the lead author.

[3] A random number generator was used to select 5 per cent of the households for each municipality. Households on the island are recorded by number for each municipality; these records are available at the state statistics office. The survey was designed and conducted by the authors in the local language with the help of two Kosraean interns from the University of Hawaii-Hilo, Tara Tara, and Paliksru Brooks.

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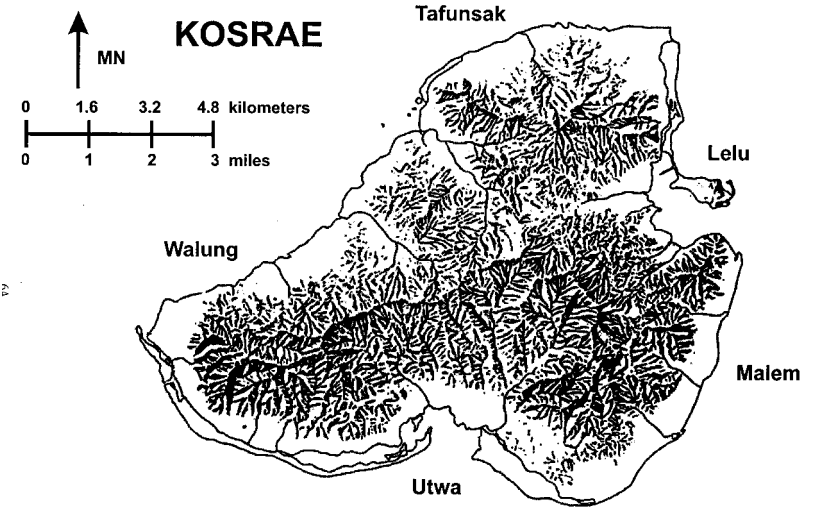


Figure 3

ment sector jobs, private sector jobs, and subsistence or informal activities. Many households had more than one form of employment and were grouped in the following way: those with at least one adult employed by the government were placed in the government category; those with at least one adult employed in the private sector and none employed by the government were placed in the private category; and those with all adults working outside of the government and private sector were placed in the subsistence category. Although this grouping is not a direct representation of income, it provides some insights into the current use and value of mangroves by employment category.[4] It also provides some indication of how the use of mangroves might change if the US Compact Agreement is withdrawn, and many government sector jobs are eliminated.

The following section of the survey focused on individual perceptions about the role and importance of mangrove ecosystem functions. With much of Kosrae's population living in close proximity to mangrove swamps, our hypothesis was that they would be knowledgeable about the direct and indirect services that mangrove ecosystems provide. Questions in this section pertained to storm protection, shoreline erosion, water quality control, and support of coastline fisheries. Respondents were also

[4] Our categories of employment are closely correlated with the employment statistics from the 1994 census (Office of Planning and Statistics, 1996). In the census, 78.5 per cent of the total labor force was employed in the formal sector (55 per cent in the public sector), and the remaining 21.5 per cent was employed in informal agriculture, fishing, and subsistence activities. The distribution of our sample was: 58 per cent public sector, 23 per cent private sector, and 19 per cent subsistence and informal activities.

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asked about their direct use of mangrove resources, including the collection and consumption of fuelwood and mangrove crabs.

In the final section of the survey, respondents were asked a series of contingent valuation questions that were designed to elicit their willingness to pay for the protection and use of mangrove swamps. Our primary goal was to assess the local population's perceptions of market and non-market values in relation to their use of mangrove ecosystems' direct and indirect services. We were particularly interested in their perceptions of mangroves' monetary value given the broad range of services that mangroves provide to the local population free of charge, and the subsistence nature of many of the households.

Direct economic services of mangroves

Mangrove swamps on the island of Kosrae generally constitute public land. Access to mangroves traditionally has been open and free, and there are no restrictions or fees for fishing or hunting in mangrove forests. The Kosrae State Department of Agriculture and Land attempts to regulate land development in mangrove swamps and extraction of mangrove trees; however, the enforcement of regulations on fuelwood collection is limited by state resources. As a result, fuelwood is still extracted for household use and for sale in the local market.

Approximately 90 per cent of all households surveyed use some mangrove wood for cooking, and almost one-third rely on mangrove wood as their primary source of cooking fuel.[5] Mangrove wood is also used to construct buildings, although most modern buildings are constructed primarily with other materials. Mangrove poles are still used widely, however, for framing domestic cook huts and houses. Based on the use for cooking alone—which is by far the predominant use of mangrove trees on the island—the gross value of wood consumed (calculated at local market prices) is equivalent to roughly 3.5 per cent of mean annual household income.[6]

Extrapolating from the survey data, the total gross value of mangrove wood used for cooking on Kosrae was approximately $278,500/year in 1996. This value is substantially higher than an earlier estimate of $130,000/year (Lal, 1989). The difference between the two estimates reflects a 40 per cent increase in the monthly use of mangrove wood for cooking between 1989 and 1996, and a 50–70 per cent increase in the market price for mangrove wood depending on the type of wood and quality.

[5] One-quarter of the households on Kosrae use mangrove wood for cooking three times a day, and one-third use mangrove wood twice a day (Office of Planning and Statistics, 1996). In addition to everyday cooking use, many households use mangrove wood for *umbs*, which are a type of earthen oven consisting of heat-conducting rocks piled among a stack of burning mangrove wood. *Umbs* are used throughout the island to prepare traditional Kosraean dishes for Sunday dinners, special holidays, and ceremonies (especially funerals).

[6] This calculation is based on 1993 income data, which are the most recent data available from the Office of Planning and Statistics (1996). In 1993, the mean annual household income was $9,686, and the median annual household income was $6,739. The mean and median annual individual incomes of those in the labor force were $4,753 and $3,253, respectively.

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Table 1 *Value of catch for fish found in the near-shore zone, Kosrae (US $, 1995)*

Common name	Family name	Value ($)	% of total fish catch
Surgeonfish	Acanthuridae	4,164	7.23
Rudderfish	Kyphosidae	2,032	3.53
Jacks	Carangidae	1,062	1.84
Parrotfish	Scaridae	1,453	2.52
Grouper	Serranidae	689	1.20
Squirrelfish	Holodentridae	1,596	2.77
Snapper*	Lutjanidae	276	0.48
Rabbitfish*	Siganidae	1,639	2.84
Mullet*	Mugilidae	2,278	3.95
Emperorfish*	Lethrinidae	1,055	1.83
Goatfish*	Mullidae	740	1.28
Octopus	Cephalopoda	441	0.77
Total		17,425	30.24

Note: * Fish species that the respondents identified to be directly reliant on mangrove swamps for food, reproduction, and protection. The other species on the list are believed to be indirectly reliant on mangroves for nutrient supplies that flow into the near-shore zone.
Source: Department of Marine Services, 1996.

While fuelwood collection remains an important economic activity on the island, the survey data indicate that the Kosraean population derives an even greater direct benefit from the collection of mangrove crabs. Mangrove crabs are collected by over 40 per cent of all households on Kosrae and are then eaten in the home or sold in the market. Based on survey data, the gross market value of crabs collected in 1996 was about $550,000/year, almost twice the value of firewood.

In addition, the survey data indicate that the majority of households fish in the near-shore zone; 90 per cent of those households consume their catch at home and do not sell fish in the market. Because fishing is such a frequent activity of households on the island, respondents had a difficult time remembering exactly how many fish, and which species of fish, they catch each week or month. Table 1 lists the estimated value of reported catch of fish found in the near-shore zone, which amounted to $17,000 in 1995. Based on this value, it seems reasonable to estimate the total reported and unreported catch at approximately $170,000/year in 1995 and 1996.[7]

The total value of the mangrove swamp area on the island associated with direct uses is just under $1 million per year—28 per cent from wood, 55 per cent from crabs, and 17 per cent from fish. This amount reflects gross income and does not account for the costs of harvesting the products—mainly the opportunity cost of labor, which is typically quite low,

[7] This value was calculated by extrapolating the reported market value of $17,000, which represents 10 per cent or less of the total catch, to the remaining 90 per cent of total fish caught that is consumed at home.

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especially among Kosrae's subsistence households.[8] The minimum wage for private- and public-sector employees was $0.90/hour in 1996, and the typical informal wage was $0.70/hour. Using these wages as accounting prices for labor, the total net value of direct mangrove services (subtracting only labor costs) is $666,000 per year.

It can be argued, however, that the social accounting price of labor is actually closer to zero, and hence the net value is approximately equal to the gross value. Within the entire survey sample, there were an average of four adults and four children per household, and 1.6 adults per household on average who were formally employed. For government employees, who comprise over one-half of the labor force, the work week was only 32 hours per week in 1996 due to fiscal constraints, and it has since been reduced to 28 hours per week. The total amount of time spent by households on harvesting fuelwood, mangrove crabs, and fish was approximately 12 hours/week for the subsistence sector, seven hours/week for the private sector, and six hours/week for the government sector. Across all sectors, therefore, there appears to be ample labor at a relatively low opportunity cost to collect mangrove crabs, fuelwood, and fish (even excluding children for such tasks).

When the estimated economic values of mangroves are converted to a land area basis, each hectare of mangrove swamps is worth between $426/year and $640/year (net) in 1996 prices.[9] A sustainable stream of $426–640/ha/year would produce a real present value of $4,239 to $6,350 per hectare if discounted at 10 per cent.[10] Land-use values of this magnitude are significant. By means of comparison, the market value in 1996 for a hectare of prime agricultural cropland in Iowa—the heart of the breadbasket in the United States—was also $6,350 (Duffy, 1996).

Distribution of direct benefits

In addition to the levels of income derived from mangroves, the survey data indicate that relatively poor people in the subsistence category benefit disproportionately from the resource's direct services. Although there is no

[8] Equipment costs tend to be insignificant for these activities. Most of the fishing in the near-shore zone is done with gill nets (DesRochers, 1989), and axes are used more frequently than chainsaws in harvesting fuelwood.

[9] These values are based on current market prices for the products (fuelwood, crabs, and fish) and two assumptions for the accounting price of labor ($0; $0.70–$0.90/hour). The values are aggregated over households and mangrove land area on the island. They therefore represent an upper bound for marginal value estimates of incremental use, and a lower bound for average estimates of total use. Similarly, the $426–640/ha. numbers represent an average product (or at least an intra-marginal product in that it is an average over a substantial area) times a marginal value. They thus underestimate the average value product and overestimate the marginal value product under the usual assumptions of diminishing returns to scale and diminishing marginal utility.

[10] For comparison, the real present value of a $640/yr income stream would be $11,970 at a 5 per cent discount rate, $5325 at a 12 per cent discount rate, and $4260 at a 15 per cent discount rate. The real net present value of a $426/year income stream would be $7,966 at 5 per cent, $3,544 at 12 per cent, and $2,837 at 15 per cent.

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Table 2 *Use of fuel by employment sector (per cent), 1996*

Employment sector	Wood	Kerosene	Electricity	Combined
Government	22	76	40	44
Private	11	18	40	34
Subsistence	67	6	20	22
Total	100	100	100	100

Note: p-value = 0.003.

Table 3 *Mean effort expended and success of mangrove crab trapping by employment category, 1996*

	No. of trips/mo	No. of crabs collected/mo
Subsistence	4.0	38
Non-subsistence	1.1	12

Note: p-value 0.007 and 0.037.

significant difference among employment categories with respect to inter-reef fishing, the subsistence sector relies more heavily on mangroves for fuelwood and crabs than do the government and private sectors (tables 2 and 3).

A significantly greater proportion of the households that primarily use wood for cooking are in the subsistence category; those in the government- and private-sector category rely more heavily on kerosene and electricity for cooking (table 2). Similarly, households in the subsistence category make more trips per month to the mangroves to collect crabs—and hence collect more crabs overall—than households in the non-subsistence sectors (table 3).[11] The greatest number of crabs is collected in areas where mangrove swamps are most abundant, such as the remote municipality of Walung.

Based on these results, the total amount of direct income accruing to each sector can be calculated (table 4). Assuming (perhaps conservatively) that the implicit income derived from inter-reef fish catch is equal for all sectors, the data show that the subsistence sector derives over half a million dollars of gross benefits from direct mangrove services annually, which is equivalent to about 58 per cent of the total gross market value in 1996. The private and government sectors derive 22 per cent and 20 per cent of the total gross market benefits, respectively.

On a net value basis, the subsistence sector derives an even greater share of the benefits. The proportion of net revenues from mangrove products (assuming an opportunity cost of labor of $0.90 and $0.70 for the non-subsistence and subsistence sectors, respectively) are 75 per cent for the subsistence sector, 21 per cent for the private sector, and 4 per cent for the government sector.

The results in table 4 indicate that there are high returns to labor from

[11] Households in the government and private sectors are grouped together in a 'non-subsistence' category because there was no significant difference in their crab collection activities. There was also no significant difference among subsistence and non-subsistence groups in the number of crabs collected each trip.

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Table 4 *Income earned from mangroves by employment category, 1996*

	Gross income earned from mangroves ('000 US$/year)	Share of gross income (%)	Net income earned from mangroves ('000 US$/year)	Share of net income (%)
Subsistence	583	58	501	75
Private	219	22	142	21
Government	196	20	23	4
Total	998	100	666	100

resource extraction at the margin, which raises the question of why resources on the island are not extracted at a much higher rate. One answer is that the market for mangrove products is demand constrained: it is generally cheaper for households to harvest products themselves than to buy the commodities in the market; fishing in the near-shore zone is considered to be a social activity and a local hobby (as well as a food source); and significant export industries for near-shore fish and mangrove crabs have not been developed. The survey data show that households in all categories consume a portion of the fuelwood, mangrove crabs, and fish that they harvest. The data also show that the subsistence sector supplies the largest share of these products to the local market, and the government sector purchases the largest share from the market. If a significant number of government-sector jobs are eliminated with the end of the Compact of Free Association with the US, market demand for these products most likely will contract—causing market prices to fall—despite the fact that the total consumption of these products may actually increase.

Moreover, the economic and ecological dynamics of the system are highly interactive.[12] For instance, substantial growth in fuelwood harvesting, resulting from a decline in formal employment and incomes on the island, could increase the number and extent of gaps in the canopy. An increase in gap area, in turn, might lead to the regeneration of lower-quality tree species that are far less valuable than the species currently preferred by residents for cooking (Ewel, Zheng, Pinzon, and Bourgeois, in press; Tara, 1997). Gap formation and decreased biomass would also cause mangrove crab and near-shore fish populations to decline, resulting in a further drop in total output. Rising demand for fuelwood per capita, coupled with steady population growth and a decline in per capita incomes, could thus place enormous strain on mangrove resources—and consequently on surrounding fisheries—unless the implicit value of direct use is made explicit in the market.

[12] The economic and ecological dynamics of mangrove ecosystem function and use on Kosrae are the focus of our ongoing work with the Pacific Institute of Forestry and Princeton University. A project to model these dynamics was recently funded by the McArthur Foundation and will run from 1998–2001.

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Table 5 *Ranking of the importance of storm protection by mangroves (per cent of total respondents)*

No importance	Low	Moderate	High	Extremely high	Do not know
1.8	3.5	26.3	56.1	7.0	5.3

Table 6 *Detection of erosion through river color change and sea level change (per cent of total respondents)*

Rivers turning more brown			Sea level change			
No	Yes	Do not know	No change	Higher	Lower	Do not know
21	58	21	10.5	66.7	10.5	12.3

Table 7 *Importance of mangroves in protecting the reef through erosion control (per cent of total respondents)*

No importance	Slight	Moderate	very	Extremely	Do not know
0	10	31	40	14	5

Non-market ecosystem services

A central hypothesis of our study is that the people of Kosrae have an appreciation of the range of ecosystem services provided by mangroves that extend beyond the direct uses described above. In order to test this hypothesis, we asked the respondents a series of simple questions related to mangrove ecosystem services and asked them to rank the importance of a number of these services. These questions were designed as a prelude to the contingent valuation section of the survey. Specifically, we were interested in gauging the ability of respondents to answer a set of hypothetical contingent valuation questions that reflect their values of both the market and non-market benefits of mangroves. Our assumption was that if respondents had a good understanding of the indirect ecosystem services, then contingent valuation could provide additional information to the direct use values discussed in the previous section, particularly with respect to the value that respondents attach to keeping mangrove ecosystems in tact.

The results of the survey indicate that there is no significant difference in knowledge or perception of indirect services among employment groups. For the sample as a whole, the data show a fairly high level of awareness of ecological functions related to storm protection, shoreline erosion control, reef protection, and inter-reef fishery maintenance. Fifty-six per cent of the respondents ranked the role of mangroves in storm protection as very important, and another 7 per cent ranked storm protection services as extremely important (table 5). This ranking is surprisingly high, given that Kosrae is located outside the main typhoon path for the western Pacific region, and it rarely experiences strong winds and large waves characteristic of severe and damaging storms.

A majority of the people surveyed also detected soil erosion associated with land use change and mangrove destruction on the island (table 6).

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Table 8 *Water quality indicators: perception of Kosraeans of preferable location for piggery and dump (per cent of total respondents)*

	near	far	does not matter
best location for piggery	31	59	10
best location for dump	7	91	2

Table 9 *Ranking of mangroves' overall importance to Kosrae's economy and environment (per cent total respondents)*

No importance	Low	Moderate	High	Extremely high	Do not know
0	6	16	53	16	9

Fifty-eight per cent of the respondents noticed that the rivers flowing into the lagoon have turned increasingly brown with sediments during the past five to ten years. Moreover, two-thirds of the respondents thought that the sea level is higher now than it was five to ten years ago. Although many people did not understand the cause for this change, roughly one-fifth of the respondents attributed it directly to shoreline erosion.

In addition, most respondents made the connection between erosion and the quality of the inter-reef fishing zone. Ninety-three per cent felt that mangroves are important for supporting shoreline fisheries; the specific functions mentioned in this regard were the provision of food and nutrients (89 per cent), fish protection (22.6 per cent), and habitat for reproduction (5.7 per cent). Almost all of the respondents also felt that erosion had negative impacts on reef quality and growth; 85 per cent ranked mangroves' service of erosion control for reef protection as moderately to extremely important (table 7).

The respondents appeared to be less knowledgeable about the function of mangroves for water quality control. We asked two indirect questions to test their understanding of this service (table 8): is the best location of a piggery near or far from the mangroves? and is the best location of a dump near or far from the mangroves? Since 81 per cent of the respondents raised pigs, the questions were of direct relevance for water quality maintenance and disease control on the island.

Mangroves have the capacity to absorb and recycle nutrients from livestock, human settlements, and refuse areas (Ewel, 1997); hence recognition of this service would have prompted informed responses about the ability of mangroves to assimilate waste and would have suggested a 'near' answer. However, it is also possible that the indirect nature of the question created some confusion for the respondents, who may have been concerned about 'protecting' the mangroves. Further investigation of the local people's knowledge about water purification benefits is clearly needed.

Apart from the water quality questions, the results in this section suggest that local people have a relatively sound understanding of the various ecosystem functions associated with mangroves. The respondents' ranking of the overall importance of mangroves to Kosrae was very strong (table 9).

Almost 70 per cent of the respondents thought that mangroves are very important or extremely important to the island; the reasons given for their

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importance included direct economic benefits (12 per cent), soil stability (50 per cent), and coastline protection (37 per cent). Thus a majority of the respondents not only recognized the value of mangroves' indirect ecosystem services, but they also ranked these services higher than direct economic benefits in overall importance to Kosrae.

Contingent valuation

The final section of the survey consisted of a series of contingent valuation questions that were designed to elicit the respondents' subjective values of mangrove resources in monetary terms. In this section, we asked the respondents three sets of questions: (1) the amount they would need to be compensated if the government allowed full development of the mangroves that precluded their use by the public; (2) the amount they would be willing to pay in monthly taxes to implement a management program that allowed partial use and that sustained mangrove ecosystems indefinitely into the future; and (3) the amount they would be willing to pay in the form of a monthly permit for continued access and use of the mangroves. All of the questions were unbounded in order to capture the respondents' true perceptions of monetary values associated with direct and indirect uses of mangroves. Although unbounded questions in contingent valuation surveys commonly lead to some unreasonably high estimates and many zero values (Cropper and Oates, 1992), we did not want to bias the respondents' subjective monetary assessments, especially because mangroves have always provided free services to the Kosraean population.[13]

The compensation, or 'willingness to accept' (WTA), question was asked first in order to familiarize the respondents with the nature of hypothetical scenarios, and to avoid the occurrence of strategic bias that might arise if they thought that the main purpose of the survey was to design a fee for mangrove use or protection on behalf of the government. The question was thus an important part of the survey design, but was not intended for use in the analysis. The 'willingness to pay' (WTP) estimates—which typically are an order of magnitude lower in value than WTA estimates in the literature (Mitchell and Carson, 1989)—were considered to be a more accurate gauge of the respondents' subjective value of the direct and indirect services provided by mangrove ecosystems. Before eliciting monetary values, we asked the respondents if they thought a tax or permit system was a good idea. The reaction was extremely positive; 86 per cent of the respondents felt that a tax for sustained management of mangroves was a good idea, and 80 per cent felt that a monthly permit for access was a good idea.

The actual values of WTP from the survey suggest a significant divergence between the tax and permit systems, and between the subsistence and non-subsistence sectors of the economy. Respondents who were favor-

[13] This type of bias is commonly referred to as 'compliance' bias in the literature. The other forms of bias that often occur in contingent valuation analysis are 'hypothetical' bias and 'strategic' bias. For reference, see Michell and Carson (1989) and Griffen *et al.* (1995).

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Table 10 *Willingness to pay for a management tax and use permit, 1996*

	Management tax ($/mo)	Use permit ($/mo)
Mean	67	37
Median	14	12
Mode	0	0

able to the idea of these programs were willing to pay a higher monthly price on average for a tax that is used to manage mangrove resources indefinitely than for a use permit. Moreover, respondents in the subsistence sector were willing to pay less on average than those in the formal sectors for both programs; although there was considerable variation within groups, the mean WTP values of respondents in the subsistence sector was less than one-half the mean values of respondents in the private and government sectors. The mean WTP values of the subsistence and formal sectors, respectively, were $33/mo and $74/mo for the management tax, and $21/mo and $53/mo for the use permit.[14]

Comparatively low mean WTP values by the subsistence sector suggests that their budget constraint is binding. Indeed, the income constraint influencing the WTP estimates appears to be stronger than the substitution effect associated with the use of mangroves for fuelwood. Households in the government and private sectors can more easily substitute kerosene and electricity for mangrove wood in cooking (table 2), yet they are still willing to pay more for programs that protect mangroves in the long run. This result indicates the desire by those who do not use mangroves directly to protect the resource for its ecosystem functions. It also perhaps reflects some degree of existence value among the non-users.

The mean WTP estimates for the sample as a whole, including the respondents who were not in favor of the programs, are shown in table 10.[15] These data reflect broader perceptions of value by local people on Kosrae—many of whom are integrated only partially into the monetary economy, and who have never had to pay for mangrove services in the past.

The data show a striking difference between measures in the sample. A modal value of $0/month is not too surprising given that mangroves traditionally have been a free good on the island. The mean values, on the other hand, are substantial and are in line with the 'no protest' estimates by the respondents stated above. The mean estimates for the tax and permit systems represent 8.3 per cent and 4.6 per cent of mean monthly household income, respectively. The median values are much lower and

[14] These results were calculated after removing extreme outliers, defined as those values that exceed the monthly median income per capita of $562. Entries by respondents who did not favor the idea of a tax or permit were also excluded. The number of observations in the analysis was 38 for the management tax and 41 for the use permit.

[15] Table 10 does not include extreme outliers, defined as in note 14. The sample sizes in the analysis were 48 for the tax system and 52 for the permit system.

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also more realistic given the income constraints of the local population; the median tax and permit estimates are equivalent to 2.5 per cent and 2.1 per cent, respectively, of median monthly household income.

When the median values are aggregated across Kosrae's population, the total willingness-to-pay for the protection and sustained use of mangroves is $1.26 million per year with the tax system and $1.08 million per year with the permit system. The stated use value reflected in the permit system estimate is well within range of the revealed preference value of mangroves, estimated earlier at up to $1 million per year.[16] The aggregate willingness to pay for broader protection and management of mangroves through a tax system is higher and reflects an implicit premium for indirect ecosystem services; these services were shown in the previous section to be of high value to respondents. Indeed, their recognition of the market and non-market values is testimony to the knowledge that the Kosraean population has about the essential role that mangroves play in their lives.

Comparison with similar studies

There have been relatively few published studies on contingent valuation in developing countries. Those that exist have focused on the demand in poor countries for education (Thobani, 1983; Mingat and Tan, 1986; Jimenez, 1987), health services (Jimenez, 1987), sanitation services (Whittington , Lauria and Wright, 1993; Altaf and Hughes, 1994), and rural water supplies (Boadu, 1992; Singh *et al*., 1993; Altaf *et al*., 1993; Bohm, Essenburg, and Fox, 1993). In addition, the World Bank initiated a multi-country study of the willingness-to-pay for potable water in 1987, which resulted in several contingent valuation analyses (Whittington *et al*., 1990, 1991; Briscoe *et al*., 1990; Griffen *et al*., 1995). A main objective of these studies was to assess the demand for public services in developing regions, where such services were not being supplied by the public sector.

In comparison to these supply-constrained systems, we focused our analysis on a system in which mangrove services have always been available to the local population free of charge. Mangroves thus constitute a public good, for which property rights must be defined in order to mitigate overuse and eventual destruction of the resource. Like the other studies, a main objective of our research was to assess the demand for mangrove services, but in this case, by residents' willingness-to-pay for their protection and sustained use, rather than for their initial availability.

The results of our research are nevertheless consistent with the other contingent valuation studies in developing countries. It is often assumed, for example, that as long as the financial requirements for obtaining potable water do not exceed 5 per cent of income, people will be willing to pay for the water services (Whittington *et al*., 1990). Similarly, Altaf and Hughes (1994) showed that the mean WTP for urban sanitation ser-

[16] The net value of marketable products is especially close to the contingent value estimate when the social accounting price of labor is assumed to be near zero. Kristrom and Riera (1996) cite other studies that demonstrate strikingly similar estimated values of environmental benefits using contingent valuation and revealed preference techniques.

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vices in Burkina Faso was 4 per cent of monthly household expenditures in Ouagadougou, 1–2 per cent of household income in Kumasi, and about 1 per cent of household income in Gujranwala. In our study, the median WTP values for protection and sustained use of mangroves are between 2–3 per cent of median household income. The mean WTP values are much higher (between 4–8 per cent of mean household income); these values are a less reliable indicator of total demand on Kosrae than the median values, partly because they reflect some unusually high estimates from people with high (subsidized) government incomes.

A notable result of all of the studies is that people in poor countries are willing to pay for resources and environmental services that are important to their survival, and thus the public sector need not be solely responsible for their provision. Nonetheless, the public sector may still have a role to play in subsidizing the availability of resources and services for the poorest of the poor (Briscoe *et al*., 1990). Like other studies in developing countries, our results indicate that many subsistence or near-subsistence households face a binding income constraint that creates a divergence between the use of and willingness to pay for a resource. Their income constraint does not suggest a lack of appreciation for the direct and indirect services that mangroves provide to the local population. It may indicate, however, that while poor communities are willing to pay for the use of essential resources, they may not be in a position to appreciate its 'existence' value *per se*—that is, the value of just knowing the resource exists irrespective of direct benefits to the population.

Conclusion and policy implications

Given the close connection between people and environmental resources in many poor regions of the world, the use of contingent valuation provides a useful mechanism to assess the demand for and perceived value of resources that are normally considered to be 'free goods'. It also complements revealed preference analyses of direct economic values by incorporating subjective assessments of non-market benefits associated with ecosystem services. In many situations, the value of indirect ecosystem services is thought to be extremely high even if it cannot be priced with any significant level of accuracy through market channels (Daily, 1997; Costanza *et al*., 1997). In such cases, contingent valuation provides an additional tool for assessing resource benefits in monetary terms.

Our research, along with other valuation studies that have been conducted in developing countries, confirms that it is possible to conduct a contingent valuation exercise among poor, often illiterate communities and still obtain reasonable and consistent results. This conclusion holds even when many of the respondents are not fully integrated into the monetary economy in the form of formal employment. Because many people in poor regions depend on the services in question for their immediate survival and livelihood, the hypothetical nature of the contingent valuation exercise is greatly reduced. Assessing local people's knowledge and subjective values is thus a viable way of evaluating preferences and potential markets for environmental goods and services in a developing country

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context, and provides a basis for designing management strategies that are socially acceptable.

The results of our study show that the local population of Kosrae is willing to pay more through a tax system than a permit system for mangrove protection, which implies that they place some value on the existence and ecosystem functions of mangroves over and above the value of mangroves' marketable products. The results also indicate that subsistence households obtain the greatest direct benefits from mangroves, but are willing to pay less for the sustained use of mangroves through a permit system than households employed in the private and government sectors. Valuation analyses using revealed preference and contingent valuation methods thus lead to different conclusions regarding the distribution of benefits, although the total value of benefits is roughly equal with the two methods.

Indeed, the progressive nature of direct mangrove use suggests that the government needs to worry about the potential transition in employment and incomes that could result from the end of the Compact Agreement. In order to prepare for this transition, policymakers should evaluate the economic feasibility of a kerosene subsidy (or other cooking alternatives), which would reduce the destruction of mangroves for fuelwood and enhance the direct benefits derived from mangrove crabs and coastal fisheries. The maximum sustainable yield of mangrove crabs and near-shore fish should also be assessed under different scenarios of fuelwood and timber extraction, and under different economic scenarios. For example, if viable export markets for mangrove crabs and fish are developed in the future—a situation that is not readily anticipated—then the market demand for these commodities could expand significantly, causing prices to rise. Under this scenario, unrestricted access to mangrove and fishery resources, coupled with low labor costs, could potentially lead to unsustainable harvests and a classic 'tragedy of the commons'.

Without well-established property rights for these resources, the government should thus be cautious about promoting high rates of extraction and exports of crabs and fish, lest the entire system collapse. In addition, policymakers should act conservatively on proposals for rapid land development in the mangroves, including road construction. Increased access to and destruction of mangrove forests resulting from such measures will undermine the long-run viability of direct and indirect mangrove services on the island. The repercussions will be felt by all sectors of the society, but especially by poor, subsistence households.

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