

A tropical freshwater wetland: III. Direct use values and other goods and services

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Abstract

Understanding the economic value of a wetland as well as how people perceive its role in providing goods and services can provide insight into the wetland's actual role and the kinds of policies needed to ensure sustainable use. On the island of Kosrae, Federated States of Micronesia, freshwater forested wetlands dominated by *Terminalia carolinensis* (hereafter called *Terminalia*) are often found just upslope from mangrove forests, which appear to be hydrologically connected to them. Many of these *Terminalia* forests have been converted into agroforests. A survey of 10% of the households on Kosrae showed that 89% owned some *Terminalia* land. Most grew taro, bananas, and sugar cane, either in or immediately adjacent to *Terminalia* forests. Most owned canoes constructed of *Terminalia* logs, and nearly half had harvested trees from these forests during the past year: 64% to clear land for agricultural purposes, 36% for building canoes, and 31% for other uses. *Terminalia* forests provided over \$3.1 million worth of goods to Kosraeans, primarily from agricultural production. Approximately 2/3 of those surveyed understood that *Terminalia* grows best in a wetland setting. Most thought that *Terminalia* forests provide erosion protection and improve water quality. However, very few were cognizant of the ecological links between *Terminalia* and mangrove forests. Kosraeans attached little importance to the fact that *Terminalia* is endemic to the eastern Caroline Islands. If human dependence on these wetlands increases, the integrity of *Terminalia* forests, as well as adjacent mangrove forests, could be at risk.

Introduction

Freshwater wetlands are often situated uphill from mangrove forests along tropical coastlines. Even though more than 30% of the remaining wetlands are in the tropics (Mitsch and Gosselink 2000), these coastal freshwater wetlands, which are

usually forested, are still poorly understood from both biophysical and economic standpoints. In this paper, we describe the ecosystem services provided by one type of freshwater wetland on the island of Kosrae (5° N, 165° E), Federated States of Micronesia (FSM), in the eastern Caroline Islands. We assess the economic value of products

from this type of wetland as well as the understanding of other goods and services it provides.

Freshwater wetlands dominated by *Terminalia carolinensis* Kanehira (locally called “ka” and hereafter referred to as *Terminalia*) occupy at least 5% of the land area on Kosrae (Whitesell et al. 1986; Figure 1). *Terminalia* trees grow to approximately 30 m, have large buttresses, and are a source of valuable timber. This species is now found primarily on Kosrae; stands on the neighboring island of Pohnpei, FSM, were once common but have been much reduced due to conversion to agriculture. These wetlands are of particular interest not only because of the intensity of use by Kosraeans but also because of their biodiversity value (TNC 2003) and their hydrologic relationships with mangrove forests, which may be a model for other wetlands with similar geomorphology (Drexler and Ewel 2001).

Mangrove forests provide Kosraeans with the equivalent of nearly \$1 million y^{-1} , or approximately 14% of median annual household income, from the harvest of fish, fuel wood, and mangrove crabs (*Scylla serrata* Forskål 1775) (Naylor and Drew 1998). We wanted to expand our understanding of the importance of freshwater wetlands in Kosrae by assessing economic value

of *Terminalia* forests. We were also interested in the Kosraeans’ understanding of other ecosystem goods and services provided by these wetlands. A better understanding of the services these wetlands provide may contribute not only to local decisions regarding freshwater wetland use in Micronesia, but also to an improved sensitivity to the characteristics and possible uses of similar wetland types elsewhere in the tropics. Understanding how Kosraeans value these wetlands may be useful for shaping conservation and natural resource education and management programs in remote areas.

Ecological setting

Kosrae is a small (109 km²), high-volcanic island with a mean annual temperature of 27 °C and average annual rainfall of 5050 mm (NOAA Cooperative Weather Station 914395). It is surrounded by a coral reef that extends no more than a few hundred meters from the shoreline. In 1983, approximately 97% of the island was covered by native forests, agroforests, and secondary vegetation (Whitesell et al. 1986). Agroforests occupied 2585 ha; some of these were freshwater wetlands

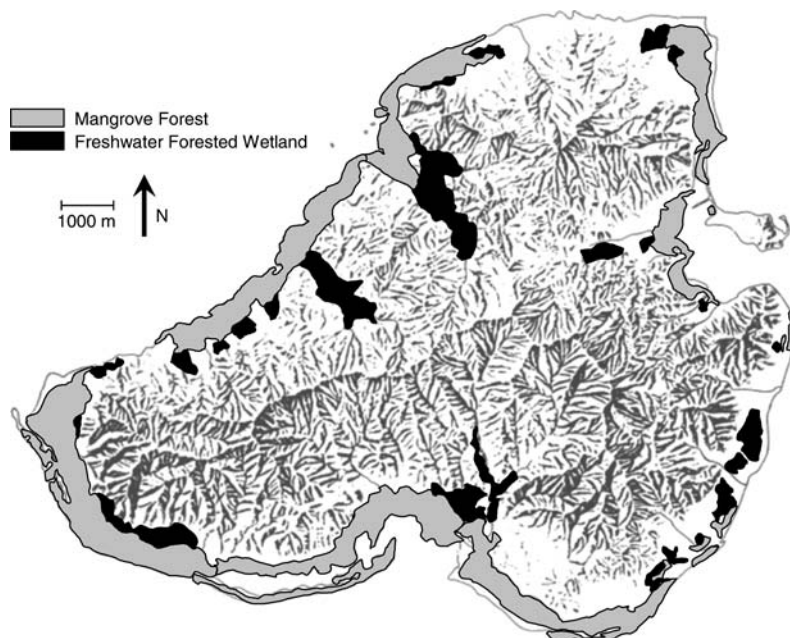


Figure 1. Location of fresh water forested wetlands on Kosrae, Federated States of Micronesia.

but most were probably uplands. 'Swamp forests' accounted for 5% of the total land area. As is true of other high-rainfall Pacific islands, much of Kosrae's area is still forested (Rolett and Diamond 2004). Most of the island is mountainous; approximately 36% of the land area is coastal plain, including mangrove forests and freshwater wetlands.

Terminalia is abundant and usually dominates wetlands adjacent to mangrove forests and in river floodplains (Allen et al. 2005). Overland flow from a *Terminalia* forest to adjacent mangrove forest has been observed, and groundwater flow in both directions has been documented (Drexler and Ewel 2001; Drexler and DeCarlo 2002). Eleven other tree and shrub species are common in these wetlands (Allen et al. 2005); *Horsfieldia nunu* Kanehira, another endemic species, occasionally dominates a wetland.

Although little is known about tropical freshwater forested wetlands, some of the natural services that *Terminalia* forests probably provide can be inferred from our understanding of temperate forested wetlands (e.g., Brinson 1990). Besides wood production and an environment suitable for some forms of agroforestry, *Terminalia* forests undoubtedly provide habitat for a variety of animal species. These wetlands also probably slow the flow of water on its route from the mountains to the sea, decreasing the rate of freshwater delivery directly to the reef and improving water quality by allowing some of the sediments to settle out before reaching the mangrove forests or reef flats.

Socioeconomic setting

FSM was part of the United Nations Trust Territory of the Pacific Islands after World War II and has been an independent nation since 1979. In 1986, it entered into a 15-year Compact of Free Association with the United States, which guaranteed payment of \$1.4 billion in exchange for exclusive military access to the nation's waterways (There is no military presence in FSM). A new compact with a lower level of funding was negotiated in 2004. The compact has provided funding for most of the country's imports (Osman 1995) and has contributed significantly to supporting public sector employment. In the mid-1990s, per capita gross domestic product was approximately \$2000/year (Osman 1995), and the median annual

household income was roughly \$6700 (Division of Planning and Statistics 1996). Since the signing of the original compact in 1986, Kosrae's population has increased from 6600 to 7700 (Kosrae State Census Report 2000).

The original Compact of Free Association was programmed to decrease payments 5 and 10 years after initiation. In Kosrae, each step-down led to a shorter workweek for government employees. At the time of this survey, government employees, who comprised over 50% of the formal workforce and 14% of the population in 1994, worked for 28 h/week, a reduction of 12 h/week from 1 year earlier.

Terminalia forests are occasionally sold but more often are exchanged for other land or goods, and sale prices are not recorded. Although the local development bank will finance mortgages for purchasing *Terminalia* forest land, the average rate is \$3–5 m⁻² (or approximately \$40,000 ha⁻¹; A. Jackson, Federated States of Micronesia Development Bank, personal communication), suggesting that sales are seldom executed in the dollar economy.

Agricultural setting

Production of giant taro (*Cyrtosperma chamissonis* Schott. Merr.), soft taro (*Colocasia esculenta* L. Schott.), and bananas (*Musa* spp.) is widespread throughout the high islands of Micronesia (Manner and Clark 1993), especially in and around wetlands like Kosrae's *Terminalia* forests. Sugar cane (*Saccharum officinarum* L.), breadfruit (*Artocarpus altilis* Park.), coconut (*Cocos nucifera* L.), and various kinds of citrus (*Citrus* spp.) may also be grown, often depending on the amount of forest cover. Lowland forests in Kosrae have apparently been used for agroforestry since 1550–1350 years BP (Athens et al. 1996), suggesting that traditional agricultural methods have been sustainable (Chimner and Ewel 2005). In Kosrae, the loss of cash income with the decreases in funding from the Compact of Free Association is likely to have increased dependence on these traditional foods.

Methods

Households were surveyed during summer 1998 to estimate ownership of *Terminalia* forests, determine

direct and indirect uses of *Terminalia* forests, and assess the level of awareness and perceived importance of ecological services provided by these ecosystems. In each of the four municipalities on Kosrae, households were randomly selected from a housing list established for the most recent census. The 98 surveys we carried out represented approximately 10% of all households on the island. There was no stratification based on age, gender, or income. The surveys were carried out in both English and Kosraean.

The area of *Terminalia* forests owned by each household was estimated by measuring from local landmarks. Values for crops, animals, and trees harvested were based on market prices during the time of the surveys. For crop production, hunting, and building canoes, the use of machinery and production inputs was minimal and in most cases nonexistent. Therefore, the only significant cost was labor, which was calculated using the public sector minimum wage (\$1.49/h) and the average time spent for each activity. Thus, the difference between gross and net values reflected only the cost of labor.

The survey also explored perceptions about natural services provided by *Terminalia* forests. Respondents were asked to rank the importance of a short list of services that are commonly attributed to freshwater forested wetlands: sediment retention, decrease in water velocity, and sustenance of biodiversity, including wildlife habitat. When follow-up questions were asked to obtain reasons why a characteristic was considered to be important, the interviewers were careful not to bias the responses by suggesting possible reasons.

Results and discussion

Putting a monetary value on a wetland and the services it provides to humanity can provide at least two important benefits: (1) this value can be used by a society in a risk analysis of alternative development routes, and (2) finding out which services or products are highly valued can help to determine who a wetland's stakeholders are. Knowing how people perceive the non-economic value of a wetland may also indicate to a society where more research and education are needed. Finally, although similar wetlands around the world may be valuable for different reasons

(Woodward and Wui 2001), knowing how wetlands are used in one culture may help another culture derive valuable goods and services from its own wetlands.

Extent of wetlands on kosrae

Most (89%) households owned *Terminalia* forest land, and most (80%) owned less than 2 ha. The average parcel of land owned by a household was 1.42 ha, suggesting that there are 1264 ha of cultivated *Terminalia* land on Kosrae. This estimate, when added to the area of freshwater wetlands already delineated on aerial photographs, suggests that both natural and cultivated freshwater wetlands together account for 16% of the total land area in Kosrae, making it the most common land use type after upland forest (Whitesell et al. 1986). Kosraean society may have developed in one of the most wetland-dominated areas on earth.

Characteristics of population surveyed

The average Kosraean household surveyed for this study included 8.2 people: 4.4 adults and 3.9 children. In 23% of the households surveyed, no family member was formally employed; this number was consistent with the value of 19% reported in the 1996 survey (Naylor and Drew 1998). The population we sampled was moderately well educated. Half of the respondents (50%) had graduated from high school, and 36% had some higher education. Most (79%) had spent part of their lives (mean = 6.25 years, sd = 6.0) off the island, including elsewhere in FSM (52%) but also in Guam (26%), Hawaii (15%), and mainland USA (6%).

Direct uses of Terminalia forests

Most (94%) households used *Terminalia* forests to produce crops, and most (90%) used some kind of agroforestry system that combined trees with annual agricultural crops. Rarely was a single crop grown where *Terminalia* forests were found; instead, multiple crops took advantage of different microenvironments within the wetland. For example, giant taro, which was grown by 97% of

the households, was cultivated almost exclusively in the shade of the *Terminalia* canopy, whereas bananas, grown by 92% of the households, and soft taro, grown by 84%, were often cultivated along the sides where there was less flooding and more direct sunlight. Seventy-five percent of households grew giant taro, soft taro, and bananas in some combination, producing an average of 3225 kg year⁻¹ worth of food goods altogether.

Only a few Kosraeans hunted and fished in *Terminalia* forests, usually going 2–3 time per month, primarily for freshwater eel (*Anguilla obscura* Guenther: 34% of households), feral pig (*Sus scrofa* L.: 14% of households), and Micronesian pigeon (*Ducula oceanica* Mule.: 9% of households). Animals hunted were primarily eaten at home rather than sold for income.

Households that harvested *Terminalia* trees (45%) were more likely to do so for clearing land (64%) or making canoes (36%) than for obtaining timber (18%) or firewood (11%). At the time of the survey, 47% of the households already owned canoes, 78% of which had been constructed from *Terminalia* trees. More than half (59%) of the people did not use any non-woody wild plants from these wetlands, whereas 30% did; the remainder did not know if any plants naturally found in *Terminalia* areas were used.

The value of *Terminalia* wetlands for direct uses was calculated based on the market value of crops, pigs, eels, and only those trees used to build canoes. A value for use of *Terminalia* for timber could not be assigned because of the different sizes of trees taken, the methods by which they were sold or traded, and the variety of end uses of the trees. We assumed that *Terminalia* trees harvested for canoes were used to build two-seat canoes, which are the smallest common size. Consequently, our estimates are conservative.

The gross value of these activities in 1998 was US\$3.17 million (Table 1). Based on this value, *Terminalia* land provided goods worth \$2505 ha⁻¹ year⁻¹; the gross value of agricultural

products grown on this land was \$1946 ha⁻¹ year⁻¹ (Table 2). Net values represented over 70% of gross values for both aggregate and agricultural output alone, indicative of the relatively low costs associated with crop cultivation and hunting.

The single most valuable crop raised in *Terminalia* wetlands was soft taro, followed by bananas, giant taro, and sugar cane (Table 3). The few households that hunted wild pigs in the *Terminalia* forests derived considerable value: \$4140 year⁻¹. The high density of pigs that this number suggests is due to the concentration in these wetlands of highly palatable food crops that attract wild pigs from bordering upland forests. The decrease in upland agricultural activity, such as planting and tending breadfruit trees, with increased economic activity over the last 20 year has led to increased pig activity in and around *Terminalia* wetlands in recent years.

For those 75% of households producing soft taro, giant taro, and bananas in some combination, the income equivalent of their level of production was 44% of the median annual household income in the mid-1990s. These data demonstrate that the island's population still relies on a productive agroforestry system in these wetlands

Table 1. Total annual gross value associated with all *Terminalia* forests on Kosrae in 1998.

Forest use activity	Total annual gross value (\$ year ⁻¹)	
Agriculture	Value	s.e.
Soft taro	\$ 909,619	\$ 111,960
Bananas	\$ 775,829	\$ 72,027
Giant taro	\$ 661,747	\$ 83,376
Sugar cane	\$ 112,687	\$ 27,907
Total	\$ 2,459,882	\$ 295,270
Hunting		
Feral pigs	\$ 579,600	\$ 196,533
Freshwater eels	\$ 86,088	\$ 17,908
Total	\$ 665,688	\$ 214,441
Canoe construction	\$ 40,500	\$ 5,063
Total earned	\$ 3,166,070	\$ 514,774

Table 2. Gross and net values for *Terminalia* forests on Kosrae, 1998.

Activity	Total gross value (\$ year ⁻¹)	Total net value (\$ year ⁻¹)	Gross value per hectare (\$ ha ⁻¹ year ⁻¹)	Net value per hectare (\$ ha ⁻¹ year ⁻¹)
Agriculture	\$ 2,459,882	\$ 1,750,618	\$ 1946	\$ 1385
Other	\$ 706,188	\$ 601,994	\$ 559	\$ 476
Total	\$ 3,166,070	\$ 2,352,612	\$ 2505	\$ 1861

Table 3. Average annual value per household (hh) per crop produced, type of animal hunted, and canoes constructed in 1998. Note that not all households realized the sum of these benefits because they did not harvest the same crops, hunt the same animals, or build canoes.

Forest use activity	Average annual gross value per household (\$ hh ⁻¹ year ⁻¹).
Agriculture	Gross value (s.e.)
Soft taro	\$ 1152 (\$149)
Bananas	\$ 897 (\$87)
Giant taro	\$ 726 (\$96)
Sugar cane	\$ 324 (\$84)
Hunting	
Feral pigs	\$ 4140 (\$1804)
Freshwater eels	\$ 253 (\$55)
Canoe construction	\$ 250 (\$31)

to grow staple crops (Athens et al.1996), underscoring the continued importance of the subsistence economy to Kosraeans.

Perception of natural services

Crop production is not an ecological service normally associated with freshwater forested wetlands in developed countries, but it is clearly of major importance in Kosrae. Respondents recognized that both soil type (79%) and soil saturation (71%) were important attributes that make these sites useful for these types of crops. Although crops grown in *Terminalia* forests were not grown exclusively there (only 2% thought they were), 89% thought they were the best place for growing taro. These attitudes indicate that Kosraeans have planted crops like giant taro elsewhere but prefer to plant them in a wetland. The importance of this crop in their diet and the suitability of the wetland environment may both be significant factors in the retention of these wetlands as *Terminalia* forests.

Kosraeans were aware of natural services associated with erosion control and changes in water quality often associated with wetlands (Table 4). Given the long history of agriculture in these wetlands, this understanding is likely to have come from local experience, as there has been little if any extension information provided locally on these relationships. It may also reflect the exposure to higher education and extensive time spent by many people off-island where more information on conservation is available to the public. The belief

Table 4. Perceptions of the role that *Terminalia* forests play in the landscape.

Do <i>Terminalia</i> forests provide erosion control?
Yes: 92%
Holding soil: 69%
Trapping sediments: 47%
Reducing floods: 18%
No opinion: 8%
Are the trees themselves very important in controlling erosion?
Yes: 88%
Do <i>Terminalia</i> forests affect water quality?
Yes: 85%
Purifying water: 58%
(e.g., Water coming out of the swamp looks cleaner.)
Absorbing water during flood: 30%
(e.g., Less water leaves the swamp than enters it.)
Reducing impact of downstream floods: 22%
Do <i>Terminalia</i> forests have an effect on mangroves?
No opinion: 52%
Yes: 30%
Protecting from erosion: 41%
Moderating water flow: 38%
Supplying nutrients: 10%
No: 18%

that the trees themselves are important in controlling erosion (presumably by 'reducing floods,' or slowing the velocity of floodwaters) may be one reason why people leave trees standing in the forested wetlands.

The lack of a widespread sense that freshwater forested wetlands might be affecting downstream mangrove forests (Table 4) increased our confidence that responses to earlier questions were sincere and not an attempt to 'please' the questioners. The same result would be expected from a similar survey in developed countries, because groundwater hydrology is not well understood by the lay public anywhere. In fact, there are few documented instances of groundwater influences on coastal wetlands (but see Semeniuk 1983; Giblin and Gaines 1990; Harvey and Odum 1990). Groundwater flows from freshwater wetlands to mangrove forests must have been interrupted by roads built around the island, during both the Japanese occupation before World War II and later as an American Trust Territory. Changes in groundwater flow and subsequent changes in coastal vegetation that might have been caused by these roads were probably small and gradual. This is an issue today, however, as the island government prepares to build a road across the coastal

landscape that includes the largest remaining *Terminalia* forest in the world.

Terminalia forests were not regarded by Kosraeans as harboring a unique assemblage of organisms. In spite of the existence of at least one wetland plant species endemic to Kosrae, only 21% of the respondents replied affirmatively when asked if there were any plants found only in *Terminalia* forests. The high number of respondents who had no opinion (42%) suggested that distribution of plants is generally not important to Kosraeans.

Similar responses were obtained regarding animals. More than half (55%) the respondents believed there were no animals on Kosrae that are found only in the *Terminalia* forest; 3% believed there were, and 42% had no opinion. For a small oceanic island, more than 200 km from the nearest island and 4000 km from mainland Asia, this is likely to be an accurate assessment. We know of no vertebrate species that are endemic to *Terminalia* forests.

Appreciation of need for stewardship

Respondents agreed almost to a person that *Terminalia* forests are important to Kosrae, primarily for production of food and fiber and much less for its role in environmental protection (Table 5). They were optimistic about being able to continue to use these wetlands, but there was some sense that natural services will diminish, and opinion was divided about the future for *Terminalia* forests.

Management options for maintaining productivity of freshwater wetlands on Kosrae and for conservation of these wetlands are fundamentally different from options for mangrove forests due to the distinction between public and private lands. Our earlier work indicated that the vast majority of households were in favor of public management plans for conserving mangrove forests, including the implementation of permits or taxes to regulate use (Naylor and Drew 1998). The results of our survey reflect a more limited acceptance of public management for private land resources (Table 5). However, unlike the situation for mangroves, any decline in crop productivity resulting from over-harvesting of *Terminalia* trees or from disrupting wetland functions will be internalized by private

Table 5. Attitudes held by Kosraeans about the importance of *Terminalia* forests and their future status.

How important are <i>Terminalia</i> forests to Kosrae?
Very or moderately: 98%
Ability to grow food there: 79%
Timber: 26%
Economic reasons: 23%
Environmental protection: 23%
Source of wood for canoes: 22%
Will <i>Terminalia</i> forests continue to provide natural services?
Yes: 76%
No: 20%
Increased use of forest: 95%
No opinion: 4%
Will there be less <i>Terminalia</i> forest in the future?
Yes: 50%
Population growth: 71%
Increased use of forest: 63%
No: 50%
Regeneration will replace lost trees: 82%
Other kinds of trees can be substituted for <i>Terminalia</i> : 13%
Should there be some kind of management plan to govern use of <i>Terminalia</i> forests?
Yes: 83%
Even if it affected the respondent's own land: 57%
Not if it affected the respondent's own land: 38%
No: 13%
No opinion: 4%

land owners. Downstream impacts resulting from unsustainable practices that affect public lands such as mangrove forests may not be internalized, however, and costs may be incurred by those dependent on the goods and services provided by those ecosystems.

Appreciation for broader values of a wetland

Tourists have been coming to Kosrae in significant numbers only within the last decade, and many people have no direct contact with tourists or the small tourist industry that has developed. The first response to a question about the importance of *Terminalia* forests to people other than Kosraeans (Table 6) drew some recognition that tourists might be interested in visiting these wetlands, but other answers reflected a more utilitarian view, timber production being the most frequent reason given. A more direct question about the attractiveness of these wetlands then drew the response that tourists would probably like to visit *Terminalia* forests, although only a small number of the

Table 6. Attitudes of Kosraeans regarding the importance of *Terminalia* forests to non-Kosraeans.

Are Kosrae's <i>Terminalia</i> forests important to people elsewhere in the world?
Yes: 61%
Timber: 73%
Potential to attract tourists: 20%
No opinion: 30%
Would tourists like to visit <i>Terminalia</i> forests?
Yes: 79%
No opinion: 18%
Do you visit <i>Terminalia</i> forests other than for hunting and agriculture?
Yes: 37%
Relaxation: 56%
Recreation: 44%

respondents themselves valued the forests for relaxation or recreational purposes.

None of the respondents thought that *Terminalia* forests were important for reasons associated with global biodiversity. It appears that the issue of global biodiversity and its importance to Kosraeans or others has had little impact on this remote island, in spite of people's exposure to both higher education and conservation attitudes in more developed countries.

Conclusion and outlook

Terminalia forests and mangrove forests together account for a significant proportion of the inhabitable land in Kosrae. Wetlands are therefore very significant to this island, both economically and ecologically. Kosrae's population has traditionally relied on a productive agroforestry system based largely on *Terminalia*-dominated wetlands to grow staple crops, and the importance of maintaining many of the natural characteristics of this wetland for both crop production and hydrologic functions is appreciated by most households. The fact that *Terminalia* and mangrove forests together provide direct economic benefits of approximately \$4 million annually (equivalent to approximately 60% of median annual household income) points out how important it is that policies affecting their use be consistent with practices that ensure their sustainability.

Creating greater institutional and public awareness of the natural goods and services that these wetlands provide is increasingly important as

external funds decline. Even so, with greater awareness comes the likelihood that increasing dependence on these wetlands, as well as on other natural resources on the island, may compromise the integrity of the resources themselves. Continued use of *Terminalia* forests probably does not threaten them (Chimner and Ewel 2005). Instead, such activities as drainage for conversion to commercial agriculture or other development projects could cause significant declines in productivity. Any proposed development, even though it might bring in foreign revenue to support such needs as education, public health, and purchase of fossil fuels, should take into account the risk to the Kosraean people of threats to its wetland-based subsistence economy.

Both the importance of freshwater wetlands and their vulnerability to changes brought about by the demands of a modern, global economy mandate that a greater understanding and awareness of wetland landscapes be sought both on and off the island. This survey has indicated how island attitudes might affect continued use of these resources. In particular, the high values that citizens of developed countries place on endemic species and biodiversity in general are not necessarily held in less developed countries. Because of this, the interaction between the economic and ecological dynamics of these wetlands is not very predictable.

The common occurrence of freshwater wetlands adjacent to mangrove forests suggests that similar landscapes elsewhere may be important to local economies. For instance, forested wetlands dominated by hardwoods such as *Pterocarpus officinalis* (Jacq.) and by a variety of palms are common in coastal areas in northern South America and the Caribbean. Some of these have been reclaimed for agriculture, and agroforestry systems similar to Kosrae's have been proposed, along with plantings of commercially important species (e.g., Bacon 1990). Understanding the ranges of roles that these wetlands can play in coastal landscapes and societies can provide valuable information to policy makers who should understand the full scope of goods and services provided by local ecosystems.

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