

Migration, Markets, and Mangrove Resource Use on Kosrae, Federated States of Micronesia

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Abstract

The Micronesian State of Kosrae is a prototype of an island economy prone to the forces of economic crowding. The average family size is large, the land area of the island (particularly the habitable portion) is extremely small, economic activity is limited mainly to a U.S.-funded bureaucracy, and household dependence on natural resources for fuel and food is high. Here we analyze how economic crowding--and the mitigation of economic crowding through trade and migration policies--affects mangrove resource use on Kosrae. A comparison of household survey data from 1996 and 2000 indicates that despite decreases in U.S. foreign aid and public-sector jobs in recent years, average household consumption of mangrove wood and mangrove crabs has not increased. This counter-intuitive outcome is due primarily to the mediating effects of migration and remittances that have helped to relieve population-driven demand for mangrove products and to sustain growth in imported fuel and building materials that substitute for mangrove wood. Our results suggest that as the next phase of the U.S. Compact Agreement with the Federated States of Micronesia is negotiated, a critical factor for sustaining the island's natural resource base will be the retention of open access for Kosraeans to live and work in the U.S.

Introduction

Coastal ecosystems worldwide face heightened threats from population pressure and accelerated economic activity. Consumption of coastal resources, including mangroves, fisheries, and beaches that cater to tourists, is now seen as a critical force mediating population-environment interactions along the world's coastlines; however, the socioeconomic, political, and historical factors that determine the structure and patterns of consumption are often poorly understood. Island ecosystems are useful venues for assessing natural and cultural change--and the interactions between people and the environment--because they contain relatively small-scale, bounded landscapes (Kirch and Hunt 1997). Islands also lend themselves to discrete patterns of resource use and well-defined socioeconomic systems. They thus serve as a useful foundation for studying the dynamics of the population-consumption-environment relationship, particularly

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as the boundaries of population and consumption expand in response to economic globalization and increased migration.

Human populations and natural ecosystems of islands, especially oceanic islands, are also vulnerable to external disturbance because of their geographic isolation. The expansion of global markets and migration presents new pathways for the spread of exotic species and pathogens to island ecosystems, and new opportunities for resource-based exports. At the same time, opening markets for imported goods and services and providing an outlet for population growth through emigration help to relieve pressure on island resources. In this paper, we assess the population-consumption-environment interactions related to mangrove forest resources on the island of Kosrae in the Federated States of Micronesia (FSM). The central question of our study is whether economic markets and migration aggravate or alleviate consumption pressures on the island's mangrove resources. A related question--and one more difficult to answer--concerns the implications of global markets and migration for resource stewardship in the long run.

The island of Kosrae presents an excellent microcosm for assessing the interactions among natural resource use, changes in population size and structure, and socioeconomic forces. The current population, estimated at 8150 people, is growing at a natural rate of 3%; average household size is 7.5 people; and 46% of the population is under the age of 18.² Like many high islands in the tropics, Kosrae has a wealth of natural resources that has supported human populations for centuries. A large, intact mangrove forest covering roughly 1500 hectares, and two-thirds of the island's coastline, is considered public land. This land traditionally has been accessible to all people on the island with no restrictions or fees.

The consumption of mangrove trees for fuel, mangrove crabs, and the dozen fish species that live in or around the mangroves was valued for Kosrae at \$1 million (net) annually in 1996 (Naylor and Drew 1998). The same study showed that households accrued additional value from mangrove services in the form of erosion control, flood and storm protection, and wildlife habitat. This snapshot underscored the importance of mangrove resources to the inhabitants of Kosrae, but it provided few insights into the socioeconomic determinants of mangrove use or the change in mangrove use over time in response to population growth and trade and migration policies. In particular, the earlier study left open the question of how the termination of the current 15-year economic cycle of the Compact of Free Association, signed between the U.S. and FSM in 1986, might affect the dynamics of mangrove resource use by altering financial flows, employment, and migration patterns on the island.

² The estimated population level was obtained by personal communication with the Kosrae Division of Planning and Statistics in preparation of the 2000 Kosrae Census. The other demographic data come from our 2000 survey, which is described later in the paper.

In this study, we look at how economic crowding—and the mitigation of economic crowding through trade or migration policies—affects mangrove resource use on Kosrae. Economic crowding arises from increasing pressure on the economic resource base (which for Kosrae is almost entirely the natural resource base), caused by population growth, stagnant incomes, and limited substitution in consumption via imports.³ We begin by discussing the ecological characteristics of the island, the historical patterns of population growth and economic control, and the current socioeconomic and policy conditions—including the Compact of Free Association—that jointly determine the patterns of mangrove resource consumption. The framework for analyzing population-consumption-environment linkages is described in the following section, with specific attention to the role of international markets and migration as mediating factors influencing consumption. The methods and results of the socioeconomic study we conducted in 2000 are then discussed and compared with those of our 1996 survey (Naylor and Drew 1998) in order to gain a longitudinal perspective on consumption trends.

Our results have important implications for mangrove resource use and management on Kosrae, as well as for resource use on other small, isolated islands in the Pacific. By looking more closely at how socioeconomic forces, human demographic characteristics, and natural resources interact, we show in the final section how varying regional policy and market scenarios might affect resource use on Kosrae. We also discuss how the transition toward globalization and migration might alter principles of common property stewardship on small islands over time.

Kosrae in historical context

Kosraeans live on two connected islands (Lelu/Ualang) within a fringing reef in the Eastern Caroline Islands (5 °19 ' north, 163° 0' east), predominantly in the narrow coastal zone near the mangrove forests. The mangrove forests remain largely intact, although sizeable gaps have been created by fuelwood extraction in certain locations (Pinzon 1998). Some areas on the island have rich soils appropriate for agriculture, but much of the interior is occupied by freshwater swamps and precipitous mountains, and agroforestry is the main form of agriculture. Virtually all households on the island own small agroforestry plots (Drew et al. unpublished manuscript). Athens et al. (1996) trace the history of an intensive agroforestry system on Kosrae,

³ For example, without ample substitutions for goods derived from mangrove forests (e.g., fuel and building materials), population and consumption growth will place increasing pressure on the resource base, leading to resource scarcity and rising values for the goods at the margin. By analogy, unrestricted (open access) fisheries tend to increase fishing pressure, which leads to heightened scarcity and rising values for fish and, in turn, even greater fishing pressure. Our definition of economic crowding does not necessarily imply increasing returns to scale; the result depends upon the degree of restriction on resource use and the degree of substitution in consumption of the resource goods.

with breadfruit as the dominant tree crop and giant swamp taro as the main staple crop, dating back to 1550-1350 BP. Population size and density increases, beginning in 800-1200 AD, triggered territorial conquest and the emergence of a complex, hierarchical social order on Kosrae (Athens et al. 1996; Kirch 2000). Based on this archeological work, it appears that population pressures in relation to resource availability have governed the structure of Kosraean society for centuries.

During this time, Kosrae, like most of the more remote islands in the western Pacific, is thought to have been isolated, with only occasional contact from other islands. The first recorded visit by Europeans was in 1824, when the scientific vessel *la Coquille* visited for several days. Subsequent stops by whalers and the eventual establishment of Christian missions began an inexorable process of cultural and ecological change. The entry of outsiders also began a period of sharp population declines and increases that has characterized the island for almost two centuries (Gorenflo 1993). Diseases such as syphilis, influenza, and measles, and possibly a typhoon as well, reduced the population on Kosrae to only 300 individuals in 1880 (Gorenflo 1993). The highly structured, hierarchical social system that existed prior to European settlement was lost in the process (Hezel 1983; Peoples 1985), and a more egalitarian system was established under the guidance of the missionaries on the island. Along with the social system, the Kosraeans' traditional religion and belief systems were largely, although not completely, abandoned.

The Japanese occupied Kosrae from 1914-45, further suppressing the indigenous Kosraean culture. Prior to World War II, the number of native Kosraean people increased steadily under Japanese occupation as a result of intensive agricultural development, imported food supplies, increased economic activity, and the provision of education and health care (Falgout et al. 1995). This period was followed by a famine toward the end of the war when an embargo left Japanese troops and Kosraeans alike unable to provide enough food for themselves (Gorenflo 1993). Countless numbers of Kosraeans died of hunger at this time. The U.S., assigned to administer the UN Trust Territory of the Pacific Islands (TTPI) at the end of the war, left the severely diminished population of Kosraeans alone to manage their own recovery. In the early 1960s, a change in policy led to a rapid influx of money and other forms of assistance. This influx, in turn, initiated dramatic changes in infrastructure, diet, and educational opportunities on the island. The Kosraean population once again began to surge at a growth rate of over 3% annually (Ritter 1978).

Increased U.S. aid in the early 1960s marked the beginning of a welfare period for Kosrae that persists today. At this time, the emergence of a large state-run bureaucracy increased public sector employment and reduced subsistence living on the island (Gorenflo 1993). Kosraeans

could buy imported food, and those employed by the public sector spent much less time on their farms (Peoples 1986).

Kosrae joined with Pohnpei, Chuuk, and Yap to form the Federated States of Micronesia (FSM) in 1976. By the time the Compact came into force in 1986, the U.S. was essentially underwriting the country's economy, which led to balance of payments and government deficits that the newly independent country could not possibly sustain through its own efforts (Cameron 1991). Food, beverage, and tobacco imports comprised almost half of total imports, of which 80% came from the U.S. (Cameron 1991). Some types of food, such as rice, also flowed into the country through food aid. By the mid-1980s, Micronesia was spending approximately five times the amount it earned from exports for imported food, beverages, and tobacco alone in any given year (Cameron 1991), with negative consequences for both economic independence and human health in the country.

The Compact was created with the intent of helping FSM achieve economic and political independence (Shinn 1984; Gorenflo 1993). It brought the equivalent of more than \$3.2 billion for development assistance to the country over a 15-year period in exchange for exclusive military access to the island's waterways. These funds have contributed substantially to the economies of all FSM states during the past 15 years; however, the current funding cycle expires in 2001. On Kosrae, the government bureaucracy still employs over 50% of the formal labor force. The FSM's only significant revenue-producing resource is the deep-sea tuna fishery, with fishing rights leased to other countries, such as China. These leasing rights provide only about 10% of the money needed by FSM to maintain its current import schedule.

The decreased strategic importance of the region has generated concern that a new funding cycle of the Compact will be much less lucrative. The FSM government is hoping to receive \$20 million/year over the next 20 years in the form of a trust fund (as opposed to a block grant), and still retain U.S. government programs in education and health (Takeuchi 2000). This amount is roughly one-half of the aid received in block grants in recent years, and one-third of that received in 1986 (FSM Census 1996; U.S. DOI 1999). Scheduled cutbacks in funding that took place in 1991 and 1996 already limit the state government's workweek to 28 hours on Kosrae. Government salaries have been reduced, and early retirement is encouraged to decrease the number of employees in the public sector. These cutbacks have forced greater reliance on subsistence activities and, perhaps even more, on remittances sent back by children and other relatives working off-island.

The Compact of Free Association has provided Micronesians unlimited entry to the U.S., along with some incentives for pursuing higher education and the ability to serve in the military forces (Hezel and McGrath 1989). Micronesians often move to Guam, CNMI, Hawaii, or the mainland U.S. for employment, send back remittances to their families on the islands, and

eventually return home to take up residence. Few islands in Micronesia are more isolated than Kosrae, where there is no television, no newspaper, and only a local radio station, but through their travels, Kosraeans have developed a taste for western food and other goods.

Some reports suggest that the U.S. is now considering an end to unrestricted entry of Micronesians (Takeuchi 2000; Associated Press 2000), although this decision is not yet on the formal Compact negotiating table (Stovall 1997). The inability of Kosraeans—and Micronesians more generally—to move freely across the Pacific to Guam, Hawaii, and the mainland U.S. would have a substantial impact, not only on population densities, but also on the country's economy.

Population-consumption-environment linkages

The historical context demonstrates that Kosrae, like the rest of FSM, has landed on a path of economic interdependence, bordering on dependence. Depopulation and cultural change severed ties with indigenous systems over a century ago, limiting the extent to which Kosraeans can appeal to the successful adaptive strategies of their ancestors for resource management (Gorenflo 1993). As the population continues to grow, the prospects of developing an independent, sustainable economy with the evolved patterns of consumption become increasingly remote. If indeed the future holds continued decreases in U.S. funding, reduced public sector employment, and increases in net population on Kosrae, it is likely that more people will turn to the natural resource base for subsistence activities. Attempts to generate income from this base, such as large-scale tourism, farming mangrove crabs, and draining freshwater wetlands or clearing steep, upland forests for agriculture may jeopardize resource sustainability and further erode the island's ability to support itself without external aid.

Framework of analysis

Our central research question focuses on how changes in consumption of mangrove resources resulting from the Compact phase-out have affected population-environment interactions on the island of Kosrae. Consumption is defined in our study as the use of mangrove wood for fuel and construction, and the capture of mangrove crabs for home consumption and sale. We employ the following conceptual framework of analysis:

$$C_t = f(P_t, Y_t, C_m(t), X_t)$$

where

C_t = mangrove wood use, mangrove crab use at time t

P_t = net population growth at time t

Y_t = household income at time t

$C_m(t)$ = consumption of imports that substitute for mangrove wood, such as kerosene and imported lumber, at time t

X = exports of mangrove crabs at time t

and

$$P_t = f(PN_t, PM_t)$$

$$Y_t = f(E_t, R_t)$$

where

PN_t = natural population growth at time t

PM_t = migration at time t

E_t = government, private, and subsistence employment at time t

R_t = remittances at time t

Two aspects of this framework are noteworthy. First, employment by sector is used as a proxy for income due to the inherent difficulties in acquiring income and savings data from household interviews. Current data on changes in household income throughout the 1990s are not yet available from government sources. Government statistics show that in 1994, 55% of the labor force on Kosrae was employed in the public sector, 23.5% was employed in the private sector, and 21.5% was employed in subsistence activities (FSM Census 1996). With the phase-out of the Compact, government sector employment is declining in the number of total jobs, the length of the workweek, and wages—all of which affect household incomes on the island.

The other important feature of the model is that migration and markets for imports and exports affect the consumption of mangrove resources. Emigration provides an outlet for population growth on the island and thus reduces the net population growth rate. Emigration also generates remittances that help to compensate for income declines on the island caused by cutbacks in government employment. Import markets for kerosene and building materials provide a substitute for mangrove wood on Kosrae; however, income and foreign exchange must be available to purchase such imports. The link again to remittances is thus important. Finally, the development of export markets for mangrove crabs could increase the consumption of that resource dramatically.

Consumption variables

Mangrove forests are used extensively by Kosraeans. Several species of mangrove trees have been harvested in the past for fuelwood and construction materials, including *Rhizophora*

apiculata, *Rhizophora stylosa*, *Bruguiera gymnorrhiza*, *Nypa fruticans*, *Sonneratia alba*, *Xylocarpus granatum*, and *Lumnitzera littorea* (Devoe 1994). One species in particular, *R. apiculata*, is favored for firewood (Ewel et al. 1998) because it is an exceptionally hard wood that is long-burning and produces little smoke. Both wood and kerosene are used to cook household meals during the week. Most families build an earthen oven, or *uhm*, on Saturday to prepare the Sunday meals, which requires large quantities of wood across the island. Especially extensive harvesting is associated with funerals, when friends and relatives who gather must be fed for as little as a week to more than a month.

Increased use of mangrove wood for fuel could have a significant ecological impact on the mangrove forests, which in turn could act as a feedback to consumption over time.⁴ To date, the mangrove forests on Kosrae are predominantly intact and capable of producing a continued flow of wood products (Devoe and Cole 1998). The harvest gaps that were created in the past are relatively small and therefore self-regenerating (Ewel et al. 1998). However, people tend to harvest trees on the edges of gaps, because access is easier and falling timber is less likely to become snagged. As demands on the forest increase, this behavior creates the potential for the formation of large, non-regenerating gaps in the future. Easy access by roads or channels is increasingly concentrating harvests in small areas, and thus large harvest gaps without sufficient regeneration of *R. apiculata* are becoming more common (Pinzon 1998). There is a slight tendency for *B. gymnorrhiza*, a less desirable fuel wood, to assume dominance in the smaller gaps that do revegetate (Ewel et al. 1998).

In addition, people also harvest mangrove crabs (*Scylla serrata*) from mangrove forests, estuaries, and reefs in Kosrae. These crabs are eaten in the normal diet and especially at feasts; they are also sold to tourist hotels and sent off-island to friends and family or for commercial export. Until very recently, Kosrae had no restrictions on crab exports for either private or commercial purposes, and crabs are not farmed in any kind of aquaculture system.

Our earlier work (Naylor and Drew 1998) demonstrated a significant difference in fuel use by employment sector. Subsistence households relied more on mangrove wood as their only source of cooking fuel, and households employed in the formal sector relied on a mix of wood, kerosene, and electric stoves. The study also showed a significant difference by employment category in the number of crabs caught per household each month. Subsistence households collected three times more crabs per month than non-subsistence households did. These results suggested that mangrove wood and crab consumption would increase as more households moved into the subsistence sector with the downsizing of the Compact and a reduction of public sector

⁴ The research presented in this paper uses current and past data on mangrove resource consumption to gauge future patterns of consumption. A dynamic model that captures ecological, demographic, and economic feedbacks over a longer (future) time period is being developed as a separate effort by Bonine et al. (in prep).

employment. Future growth in crab catch depends, however, on the sustainability of mangrove forests and in crab populations as more pressure is placed on these resources over time.⁵

On the basis of the previous study, we formulated three hypotheses:

- Greater amounts of mangrove wood will be used for fuel as a result of a growing population and reduced purchasing power for kerosene imports due to cutbacks in government employment.
- Local construction materials, which come primarily from mangrove species, will replace imported materials, such as lumber and concrete, as foreign currency becomes scarcer and incomes decline.
- More crabs will be captured for domestic sale or export as government employees move into the subsistence sector and as wage incomes decline.

Migration as a mediating factor for consumption

These hypotheses were formulated in response to our observations about a likely decrease in Compact funding and its effect on government employment, but they can not be addressed without also considering changes in migration patterns. Mobility had relatively little impact on the population dynamics of Kosrae prior to the Compact. By the time of initial contact with Europeans in the 1820s, Kosraeans had lost their ability to sail across open oceans, thus limiting the possibility of emigration (Gorenflo 1993). Migration patterns started to develop in the early 1900s, mainly in the form of emigration to other areas in the Pacific to provide labor. After World War II, emigration was enhanced by economic investments within the TTPI, easier means of travelling, and better educational and employment opportunities elsewhere in the Pacific, such as Guam and the Commonwealth of the Northern Mariana Islands (CNMI) (Gorenflo 1993). As of 1985, however, relatively few citizens of FSM had migrated beyond the bounds of their country (Hezel and Levin 1987). By the 1990s--just a few years after the Compact was signed--the situation had changed dramatically (Hezel and McGrath 1989).

The provision in the Compact permitting free entry of Micronesians to the U.S. proved to be an important safety valve for faltering economic development in FSM (Gorenflo and Levin 1995). Unfortunately, detailed demographic studies of migration for FSM--and particularly for Kosrae--are scarce. What studies exist, however, demonstrate substantial population movements within the Pacific. Hezel and Levin (1996) show that in 1994 the yearly emigration rate of Micronesians to Guam and CNMI was 1.0% for FSM as a whole, and 0.5% for Kosrae.

⁵ It is also possible that crab aquaculture will be introduced to Kosrae. Without the use of sound ecological principles in production, crab farming could place a severe strain on mangrove forests, just as other types of aquaculture have done in other regions of the tropics (Naylor et al. 2000).

Although annual rates are not available, FSM census data show that Kosraeans tended to migrate more to Hawaii and the mainland U.S.; of the total number of Kosraeans living abroad in 1994, 58% were in Hawaii and the mainland U.S., 24% in Guam, 6% in the Marshall Islands, 2% in CNMI, and 10% in other areas (FSM Census 1996). The population of Kosraeans living outside of FSM in 1994 was equivalent to 15% of the population living on the island (FSM Census 1996).

An interesting feature of migration in FSM is that there appears to have been considerable back-migration, or the return of former emigrants to their original home (Hezel and Levin 1996). For many emigrants, migration is seen a means to expand educational opportunities, earn extra income for families at home, or travel through military service, without the intent of permanently living abroad. Emigrants from Kosrae maintain strong family and cultural ties and often return home after a number of years abroad. The extent of back-migration has not been adequately recorded, but it has important implications both for incomes and for changes in the value system influencing resource stewardship on the island in the long run.

After 15 years of population outflow, monetary remittances have become an important source of income for Kosraeans and residents of other FSM states. The last FSM census report to document remittances was in 1994 (FSM Census 1996), when 15% of all households in FSM reported remittances.⁶ The amount reported was equivalent to 15% of total household income. The relative importance of remittances varied across states; only 6% of households on Kosrae reported remittances (equivalent to 8% of median income), but 29% of households on Chuuk-- a much poorer state-- reported remittances.⁷ In all states, the trend in remittances showed a steady increase with no indication of a plateau or decline; already by 1994 there were signs that more dollars were flowing into FSM than out because of migration (Hezel and Levin 1996). On Kosrae, remittances have fueled expenditures for new houses, vehicles, and other imported consumption items.

The pattern of migration, remittances, and aid that has evolved in Kosrae during the past three decades is seen in many other island states around the world, e.g., in the Caribbean (McElroy and Albuquerque 1990), Western Samoa and the Tongan Islands (Gailey 1992; Macpherson 1994; Ahlburg 1994; and Brown 1998), and other islands in the Pacific (Rallu 1994). Pacific Island economies, in particular, receive considerably more aid per capita than any other country or territory in the world (Poirine 1998). Development in this region is consistent with the MIRAB (migration, remittances, aid, and bureaucracy) model articulated by Bertram and Watters (1985). MIRAB defines a development process in which remittances and foreign

⁶ Remittance data from the next FSM census in 2000 have not yet been released.

⁷ Remittances to Chuuk accounted for three-quarters of total remittances reported in FSM in 1994 (Hezel and Levin 1996).

aid are the main economic resources of the local economy. Bertram and Watters claim that this process is sustainable—and perhaps optimal—in the long run, as long as the "rent" from remittances and aid can be obtained for an indefinite period. The basis for the theory centered on the fact that colonial administrations long ago raised living standards in these small economies above the level that could be sustained on the basis of local subsistence-sector production and trade.

Most small Pacific economies do not have the international specialization required to benefit from economies of scale and comparative advantage in international trade (Poirine 1993, 1995). Experience from the Cook Islands, Tonga, and Western Samoa shows that remittances are more stable over time than receipts from agricultural exports or tourism (Poirine 1998). In Kosrae, where there are few agricultural exports and limited tourism, remittances are likely to remain an important source of income, at least in the short run. Remittances flowing back to small island states do not appear to be simply an act of altruism among family members that promotes wasteful consumption of imports and that diminishes over time. Instead, remittances often represent repayments of loans that helped finance human capital investment; money lent to relatives to help finance education; and money for family retirement (Poirine 1998). Remittances can thus play an important investment role in small economies, in addition to maintaining lifestyles and funding the consumption of imported goods.

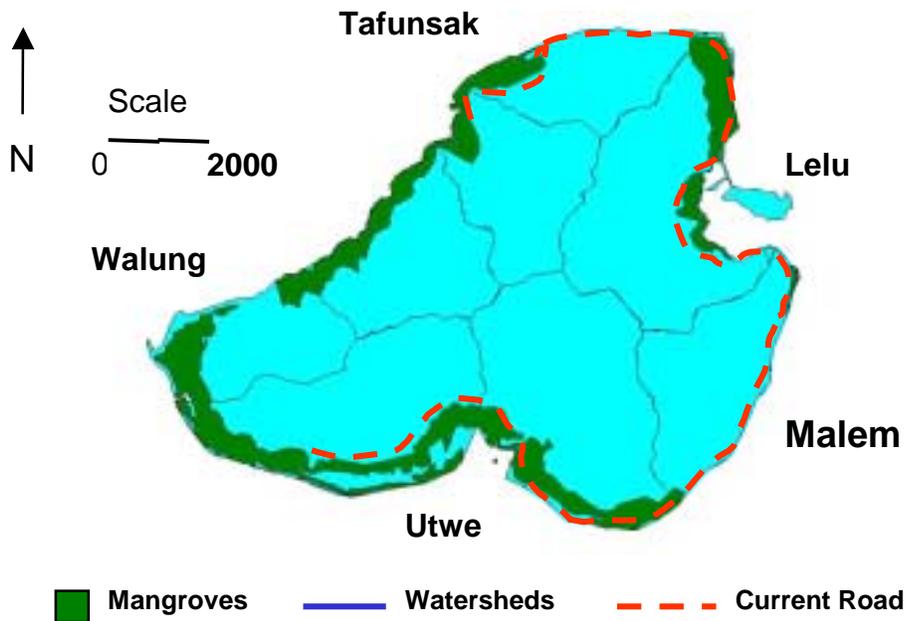
Despite the expanding role of migration and remittances in the Pacific in recent decades, we have found no studies that link the MIRAB model to the sustainability of natural resource use in island economies. Most studies focus only on the financial and social impacts of globalization and migration. Our survey, presented below, was designed to provide some insight into how open markets, particularly for labor, affect natural resource use on the island over time.

Analysis of household survey data

Methods

In order to determine recent patterns and changes in the consumption of mangrove resources on Kosrae, we conducted 100 household interviews in 2000, which covered almost 10% of the households on the island. The sample was selected randomly in proportion to the number of households in each of the five municipalities: Lelu, Malem, Utwe, Tafunsak, and Walung (Figure 1). Survey questions were directed at the male or female head of household, or both if present at the same time. Interviews were conducted in the local language with the help of interpreters who worked at various state government offices.

Figure 1. Map of Kosrae State, FSM



The first section of our survey contained questions on demographic and economic attributes of the household, including respondents' age and gender, household size and composition, education of household members, and family members living off the island. As a proxy for income, we asked about the employment activities of the adults in each household.⁸ The following section of the survey elicited information about rates, methods, and perceptions of mangrove wood and crab harvesting. Respondents were asked about household patterns of cooking fuel use for daily meals and special occasions, materials used in new building construction, household collection or purchase of mangrove wood, and methods of fuelwood harvest. They were also asked about past and current crab collection practices, perceptions on the changing abundance of mangrove crabs in the mangrove forests, and markets for crabs collected by the household (home consumption, local market, or export). Finally, respondents were asked some general questions about how they were adapting to the decline in U.S. funding

⁸ Employment was categorized as government 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 indication of how the consumption of mangrove resources is changing as public sector jobs are reduced with the phase-out of the Compact.

through the Compact, including whether or not they were spending more time working on their agricultural plots.⁹

Data from this survey were compared with those from our earlier household survey on Kosrae in 1996 (see Naylor and Drew 1998, for details). Our principal aim was to test the hypotheses described above: that mangrove wood and crab consumption by households on the island has increased as public sector employment has been steadily reduced, taking into account the possible buffering effect of remittances that have increased with emigration. The 1996 survey used similar sampling and interview methods as the 2000 survey, but it did not contain questions about migration.

Differences in mangrove resource consumption by village and by employment sector were tested using analysis of variance for continuous variables and chi-square tests for discrete counts (e.g., number of households using wood as a primary fuel source).¹⁰ Significance levels are reported in p-values.

Employment patterns

The distribution of households by employment sector in 2000 was similar to that in 1996, with the government employing at least one member of over half the households on the island. However, the share of households earning wages from the public sector dropped from 58% to 53%, while the share of households earning a living in the subsistence, or informal, sector increased from 19% to 25%. Over half of the former government employees stopped working because of mandatory retirement at age 55. The decline in government employment is understated by these numbers; with the drop in Compact funding, the length of the public sector workweek has been reduced to 28 hours (four 7-hour days), and real wages have decreased. Public sector employees have been encouraged to work on their farms on Fridays to compensate for the reduced work week.

Our results indicated, however, that once people entered a cash and wage-earning economy, they did not necessarily return to subsistence activities for their livelihood. Virtually all of the households interviewed owned some agricultural land on Kosrae. Among households currently employed by the public sector, 52% farmed less, 24% farmed more, and 24% farmed the same amount in 2000 as they did in 1996. Similarly, of the households formerly in the government sector, 47% farmed less, 21% farmed more, and 32% farmed the same amount in 2000. Respondents attributed this trend to increased commitments to wage-earning jobs or, more

⁹ To obtain a copy of the survey questionnaire, please contact the authors.

¹⁰ Multiple regression analysis was also performed on variables explaining mangrove wood and crab consumption. The results are not included in the paper because they did not add information to the ANOVA and chi-square analyses presented here.

often, to their children living off-island. Nonetheless, half of the households in our sample received some income from crab harvesting, agriculture, fishing, and handicrafts, worth on average \$2200/year or about one-third of median household income.¹¹

Employment varied significantly among the five main villages on the island (Table 1). Lelu is closest to government offices and had the highest population and density, containing 36% of the island’s population and a high proportion of government and private households. Walung, in contrast, has no road access and is accessible only by boat; accordingly, it had the highest proportion of subsistence households on the island. Tafunsak is close to the airport and has several restaurants and a fish market, and thus also had a high proportion of private sector households. Both Malem and Utwe had a large share of government and subsistence households; these villages are further from commercial and government offices and the airport, and closer to mangrove forests and to freshwater swamps where agroforestry is pursued. The differences in employment by village were consistent with the 1996 survey. Village distinctions, which reflect employment patterns, picked up much of the variation in resource use across the island, as shown below.

Table 1. Comparison of employment distribution by village, 2000*

	Percent of households in each village				
	Lelu	Malem	Utwe	Tafunsak	Walung
Government	49	61	60	52	25
Private	37	09	07	26	0
Subsistence	14	30	33	22	75

* χ^2 p<0.05

Migration patterns

Two-thirds of the households interviewed had at least one family member living off-island, and 80% of these households received remittances. These data suggested that migration rates were quite high, with an average of two people per household living off-island. Aggregated across all households, the total number of emigrants (2100) was equivalent to over 25% of the people remaining on the island, and reflected a 75% increase from the data reported in the 1994 census (FSM Census 1996). The total Kosraean population (resident and emigrant combined) grew at an annual rate of 3.6% between 1994-2000. The annual migration rate over this period was 1.76%, which reduced the net annual growth rate of the resident population to 1.82% (see Appendix A).

¹¹ This calculation is based on 1993 income data, which are the most recent data available from the Division of Planning and Statistics (1996). In 1993, the mean annual household income was \$9,686, and the median annual household income was \$6,739.

Based on the geographical distribution of expatriates in 1994, we estimated that the Kosraean population migrated to the U.S. (including Hawaii and Guam) at an annual rate of 1.64% from 1994-2000. The migration rate of Kosraeans to other FSM states and elsewhere in the Pacific during this period was only 0.29% per year. Our field survey data suggested that the share of total emigrants from Kosrae living in the U.S. and U.S. territories remained slightly above 80% over the period. These results reflect the continued dependence of Kosrae on the U.S. as a destination of emigration and a source of remittance income and education.

Our survey showed that Kosraeans emigrate mostly for employment (68%) or educational (16%) opportunities. Households with family members living outside FSM ("migrant households") tended to achieve higher levels of education than those without emigrants ("non-migrant" households). Two-thirds of migrant households had at least one adult who attended college versus just over half of non-migrant households. Similarly, 13% of migrant households had a family member currently attending college versus 9% of non-migrant households.

Although rates of emigration did not differ across villages, migration appeared to be linked to employment patterns on the island. Non-migrant households were more likely to find other formal sector jobs as government sector employment declined. Almost 20% of migrant households moved from the government sector to the subsistence sector with cut-backs in the Compact, compared to fewer than 10% of non-migrant households. More non-migrant households (30%) owned a business than migrant households (12%), and more non-migrant (27%) than migrant households (19%) worked in the private sector. These patterns suggested that households with family members overseas, many of which received remittances, had more financial freedom than non-migrant households. Ironically, households with migrants are free to pursue subsistence activities and to earn lower wage incomes on the island.

Consumption of mangrove wood

Households on Kosrae use a mix of wood (mangrove wood and upland forest species), kerosene, and electric stoves for cooking. Over one-half of the households, evenly distributed across employment sectors, cooked to some extent with mangrove wood (Table 2). The average number of mangrove bundles used per household per week decreased by over 30% from the 1996 survey; some of this difference was accounted for by a 20% increase in the use of upland forest species. Subsistence households relied on mangrove wood as a primary source of fuel more than households in the formal sector, using twice the number of mangrove bundles per week.

Table 2. Wood use for cooking by employment sector, 2000

	Percent of households using wood for cooking				Fuel use rate	
	Mangrove wood	Upland forest spp.	Upland forest spp. as primary fuel	Mangrove wood as primary fuel*	Mangrove bdl/wk*	Kerosene gal/wk*
Government	57	66	13	4	1.12	1.1
Private	60	65	9	0	1.15	1.5
Subsistence	52	40	16	16	2.66	0.9

* χ^2 , ANOVA $p < 0.05$

Most households (80%) constructed traditional *uhms* for Sunday meals, funerals, and other special occasions.¹² *Uhm* cooking decreased by almost half since the 1996 survey, however, from an average of 1.5 times per week to 0.8 times per week. About one-half (46%) of households primarily used mangrove wood for *uhms*. For the island as a whole, daily cooking accounted for 67% of mangrove wood use, and *uhm* cooking accounted for the remaining 33%. Despite the fact that *uhms* are traditionally made with mangrove wood, 41% of households at this time were using other upland forest wood species. For non-subsistence households, *uhm* cooking accounted for almost all of the mangrove wood use, and about half of the total wood use. By contrast, subsistence households used only one-half of their mangrove wood and one-third of their total wood for *uhms*. These data suggest that mangrove wood continued to be used widely for *uhms*, even by households that had the money to buy alternative fuel sources for their daily cooking needs.

Most households on the island (88%) cooked with a kerosene stove, up from 75% in 1996. On average, households cooked 15 times per week with kerosene, and only 4.5 times per week with wood. Subsistence households used significantly less kerosene per week than government and private households (Table 2). Only 11% of households used electric stoves, less than half the number in 1996.

The use of cooking fuel differed significantly among villages (Table 3). Almost all households in Lelu used kerosene as their primary source of fuel, whereas all households in Walung used mangrove wood as their primary source of fuel. Households in Utwe and Walung used significantly more mangrove wood than the other villages because of their proximity to large mangrove forests. Households in Lelu, Malem, and Tafunsak were increasingly using other

¹² Funerals are considered one of the most important traditional family and community events on Kosrae, and they often last from several weeks to over a month. By tradition, extended family and friends bring wood or food cooked in *uhms*. Our survey results indicated, however, that in 2000, about half of the households purchased food to bring to funerals, and the remainder cooked with mangrove wood (21%) or upland forest species (30%).

forest species for fuelwood. Respondents claimed that an expanding network of farm roads into upland areas, combined with the increasing number of vehicles on the island, made upland forest species more accessible. The government is currently planning to extend an existing road around the rest of the island alongside mangrove forests that had previously been accessible only by boat. This plan, already in the early stages of implementation, will open up a wider area of forest resources to households for fuel, and will likely increase the consumption of mangrove wood significantly.

Table 3. Wood use for cooking by village, 2000

	Percent of households using wood for cooking				Fuel use rate
	Mangrove wood*	Upland forest spp.**	Mangrove wood as primary fuel***	Kerosene as primary fuel	Mangrove bdl/wk*
Lelu	54	74	0	97	0.74
Malem	30	74	0	70	1.15
Tafunsak	61	61	0	83	1.39
Utwe	87	20	13	80	2.06
Walung	100	0	100	0	3.88

* χ^2 , ANOVA $p < 0.05$

** χ^2 $p < 0.001$

*** χ^2 , $p < 0.0001$

Roughly one-third of the island's households constructed new buildings in 2000, similar to the pattern in 1996. New buildings were most commonly dwellings, cookhouses, or piggeries. Only a third of the households used mangrove wood for building, as opposed to half of the households in 1996. The island-wide decrease in consumption of mangrove wood for construction can be explained by the concurrent 20% increase in the use of imported lumber and concrete. Most respondents who used imported material for construction claimed that the new government housing loan program on Kosrae allowed them to do so. Loans were widely available to households with some financial capital. Although increased use of imported lumber and concrete provided a reprieve from population pressures on mangrove resources, it may be temporary if the decline in Compact funding forces the Kosraean government to reduce the current housing loan program.

Consumption of mangrove crabs

Roughly one-third of all households on the island harvested crabs in 2000, down slightly from 40% in 1996. Total crab harvest per month decreased by 20% over the same period. Respondents indicated that they were harvesting fewer crabs now because they were growing old, because their children were either off-island or not interested in collecting crabs, or because crabs

were becoming too difficult to find. Almost all (96%) households harvesting crabs used some or all for household consumption; in addition, about half of the households sold crabs in local markets, to restaurants, or to markets off-island.

The share of households harvesting crabs was distributed fairly evenly among employment sectors (Table 4). As expected, subsistence households are more likely to sell the crabs they harvest, and less likely to buy crabs (Table 5). Private-sector households bought significantly more crabs per month than government or subsistence households; they also sent more crabs off-island.

Table 4. Mangrove crab harvest by employment category, 2000

	Households harvesting crabs		All households
	Percent of total	Avg. crabs harvested/mo	Avg. crabs harvested/mo
Government	30	22.2	6.7
Private	23	12.1	2.7
Subsistence	24	37.0	9.0

Table 5. Mangrove crab trade by employment category, 2000

	Households buying crabs		Households harvesting crabs	All households
	Percent of total	Avg. crabs bought/mo*	Ratio of crabs caught/ bought	Percent sending crabs off-island*
Government	56	1.7	0.3	36
Private	86	5.4	1.2	50
Subsistence	36	1.2	71.6	13

*ANOVA, χ^2 , $p < 0.05$

Average crab catch and trade also appeared to differ among villages (Tables 6 and 7). Walung had the greatest proportion of households harvesting crabs, likely due to the presence of a large, intact mangrove forest supporting a large crab population, the lack of a road and access by non-villagers, and the majority of households leading a subsistence livelihood. Utwe, a village at one end of the existing road, also had a large number of crab-harvesters; these households both collected and sold more crabs per month on average than households in other villages.

Table 6. Mangrove crab harvest by village, 2000

	Households harvesting crabs		All households
	Percent of total	Avg. crabs harvested/mo	Avg. crabs harvested/mo
Lelu	26	11.2	2.9
Malem	17	6.4	1.1
Tafunsak	26	41.7	10.9
Utwe	33	48.6	16.2
Walung	75	6.5	4.9

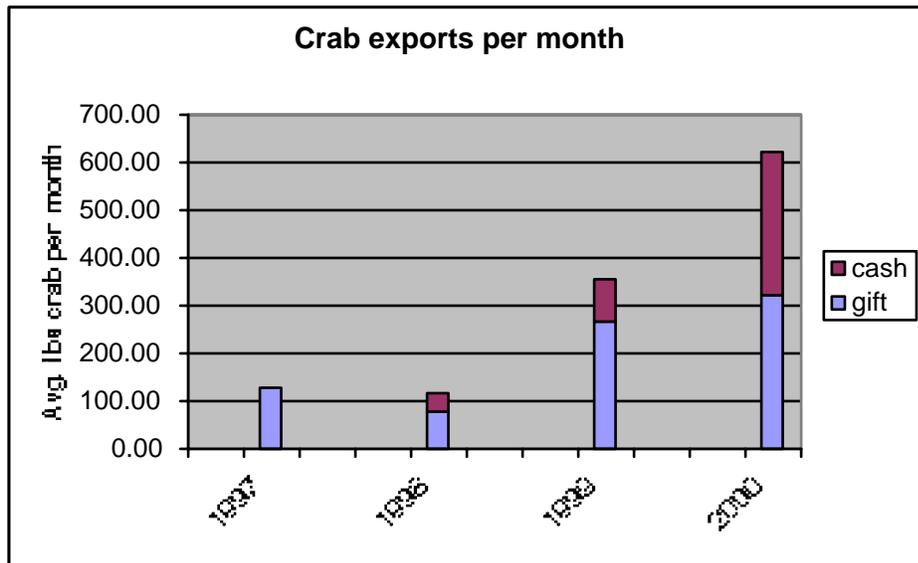
Table 7. Mangrove crab sales by village, 2000

	Households selling crabs		All households
	Percent of total	Avg. crabs sold/mo	Avg. crabs sold/ mo
Lelu	33	8.4	0.7
Malem	50	0.5	0.5
Tafunsak	67	7.7	1.3
Utwe	60	101.4	20.3
Walung	33	16.0	4.0

Larger-scale crab collecting enterprises have recently emerged in Utwe and Tafunsak (7% and 4% of households in each village, respectively, were engaged in such activities). The average number of crabs collected per month by these households was 192 for Utwe and 161 for Tafunsak. Most crabs harvested in Utwe since 1997 were exported to a single restaurant in Guam.

In recent years, private gift exports of crabs were matched by increasing commercial exports from Kosrae, primarily to seafood restaurants in Guam. According to records kept by the Kosrae Quarantine Office, total crab exports increased almost four-fold in the past four years, from 1500 lbs. in 1997 to 7500 lbs. in 2000 (Figure 2). Exports for gifts increased by about 2.5 times whereas commercial exports increased eight-fold. This dramatic change in both the number and purpose of crab exports has prompted concern over the long-term sustainability of an export-oriented crab fishery, especially considering the vast demand of large markets in Guam or Japan, which could quickly exhaust the crab supplies of a small island such as Kosrae.

Figure 2. Crab exports per month 1997-2000

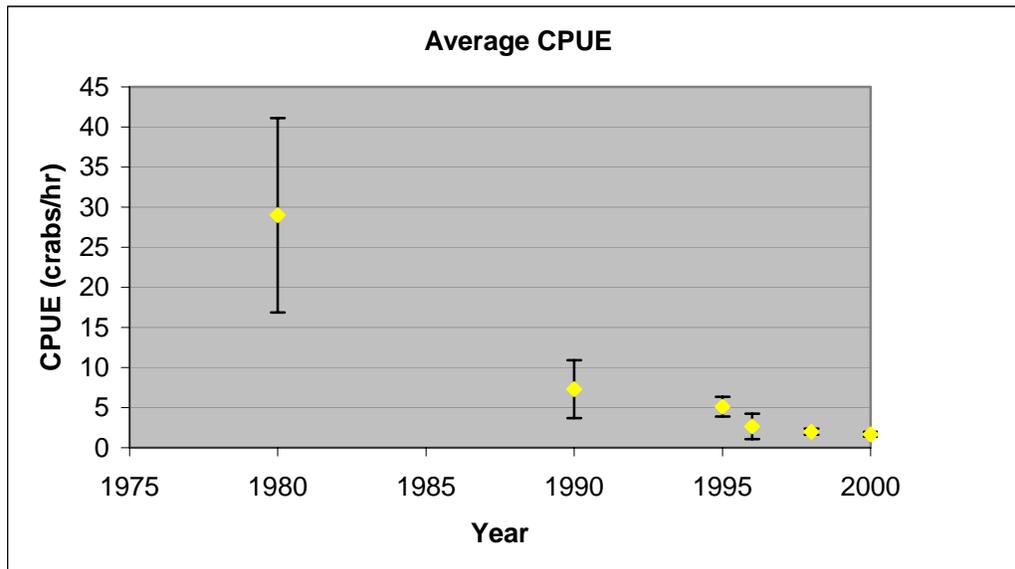


Source: Kosrae Quarantine Office

Based on reported monthly crab harvest, we estimated the current annual crabs harvest at 84,500 crabs for the island as a whole. This was a 42% decline from the 1996 annual harvest estimate of 144,800 crabs (Naylor and Drew 1998). At first glance this trend suggested a reduction in harvesting pressure on crab resources; however, the source of the harvest decrease pointed toward declining crab abundance rather than decreasing pressure. The decline in crab harvesting was partially due to a 15% decline in the number of households collecting crabs, but more importantly to a 45% decline in the average number of crab trips per month and a 37% decline in average catch per unit effort (CPUE). Eighty-five percent of respondents who harvested crabs stated that it was harder to find crabs now than several years ago. In the 2000 surveys, we inquired about past crab harvest as an additional proxy for changing crab abundance over time; anecdotal responses to this question suggested a dramatic decline (over two-thirds) in CPUE over the last twenty years (Figure 3). The decrease in catch per unit effort is a warning sign that crab abundance is declining on the island and that management efforts may be warranted to ensure the long-term sustainability of the fishery (Bonine et al. unpublished manuscript).¹³

¹³ Due to concern about a perceived decline in the mangrove crab harvest, the Kosrae State Government recently passed a law specifying a minimum harvest size, banning the harvest or exporting of females with eggs, and prohibiting the capture and sale of crabs from June to December. Without any legal means of enforcement or community involvement, however, it is unlikely that this law will be followed. Indeed, 63% of respondents who had found juvenile crabs stated they harvested them as well, 36% reported collecting females with eggs, and 58% reported buying females with eggs. Eighty-eight percent of respondents said females with eggs taste the best.

Figure 3. Crab catch per unit effort 1975-2000



Source: Field survey data, 1996, 2000

Migration-consumption linkages

Pressure on crab resources on Kosrae appears to be a function of expanding export markets as well as population-driven demand. In addition, there is some evidence of a link between migration and crab collection on the island. Households with migrants were more engaged in crab collection than households without migrants; based on our survey, average crab catch per month was 8.7 versus 1.6 for the two groups, respectively. This counter-intuitive result might be explained by the fact that households with migrants (and, by extension, with remittance income) have more financial freedom and time to collect crabs. Our data showed no difference in the number of crabs that migrant and non-migrant households send off-island.

At this point, only weak statements can be made about the relationship between mangrove resource consumption and migration on Kosrae. Data from our survey showed no statistical significance between consumption indicators and migration across households. Wood use for cooking was similar between migrant and non-migrant households, and construction was higher (although not statistically different) in the migrant group (34% of migrant households constructed buildings during the previous year versus 24% of non-migrants households). The lack of statistical significance was due most likely to the large number of households who had family members living overseas; two-thirds of the households were in the migrant category, and these households were distributed fairly evenly across employment categories and villages. As a result, trends in total consumption (migrant and non-migrant combined) of mangrove wood and crabs provided the most concrete evidence of resource change on the island.

Conclusions and implications for resource stewardship

Kosrae is a prototype of an island economy prone to the forces of economic crowding. The average family size is large, the land area of the island (particularly the habitable portion) is extremely small, economic activity is limited, and household dependence on natural resources for fuel, food, and ecosystem services is high (Naylor and Drew 1998). During the past several decades, migration and foreign aid have helped to relieve the pressures of economic crowding on the natural resource base. As U.S. aid is withdrawn and public sector jobs are reduced, however, the question of economic crowding still looms as an important policy issue for the island and for FSM as a whole.

The results of this study show that despite the decline in aid and government jobs, average household consumption of mangrove wood and mangrove crabs has not increased in recent years. Mangrove wood for daily cooking and *uhms* has decreased since 1996, and the use of kerosene stoves has continued to rise. Similarly, the use of mangrove wood for building has been offset by the use of imported lumber and concrete. The majority of households on the island have family members living overseas and receive remittances; these remittances most likely have helped to sustain the increase in demand for imported materials. If open access to the U.S. by FSM residents is repealed in the next phase of the Compact, this pattern could be reversed. In addition, if the government's housing loan program is reduced, or if the government proceeds with its plan to build a road around the island through remote mangrove forests, pressure on mangrove resources could escalate in the future. The island's upland forests are already being used more intensively than in 1996.

Our results also show that the average catch of mangrove crabs per household has declined, and that fewer households are engaged in crab collection. Nonetheless, some households are now engaged in large-scale crab collection and export activities; an increase in the rate or extent of these activities could drive the mangrove crab fishery to an unsustainable level. In recent years, there have been signs of a decline in crab abundance. Our research suggests that many households are collecting fewer crabs because they are more difficult to find.

It is clear that Kosrae is at a crossroads in terms of economic activity and resource use. Three scenarios of economic development seem plausible at this stage, each of which has vastly different implications for economic crowding and the sustainability of resources on the island. The first, and most probable, scenario follows from the first 15-year phase of the Compact: foreign aid is continued at a reduced level, and emigration of Kosraeans to the U.S. and U.S. territories is permitted on an unrestricted basis. The second scenario is that aid is reduced and that the migration clause of the Compact permitting Kosraeans open access to the U.S. and U.S.

territories is repealed. The third scenario entails continued aid and migration, and a shift toward economic activities on the island that do not place direct consumption pressure on mangrove or inland resources.

Under the first scenario, it is likely that economic growth on the island would be fueled increasingly by remittance income, and that net population growth would remain roughly stable. Although our results suggest that the impact of economic crowding on mangrove resources would be mitigated by emigration and the substitution of imports for mangrove fuel and building materials, resource stewardship under this scenario is not clear. Ostrom et al. (1999) stress the importance of a shared set of norms and resource needs for co-operative and sustainable management of common property resources. As a larger share of the island's population moves off and then back onto the island, norms are bound to change; such changes could include a decline in native knowledge of mangrove ecology, and a reduced appreciation for the goods and services generated by mangroves. Essentially, if the need to preserve common property resources becomes less important because of remittances and import substitutes, then the institutions governing resource management could also break down. A critical condition for the preservation of norms in the face of migration and markets is a stable and strong social structure (Kirch 2000).

The second scenario implies much greater reliance on the island's natural resources given Kosrae's current dependence on foreign aid and remittances. To avoid an "Easter Island" outcome under this scenario, co-operative behavior and a strong set of collective norms governing resource use would need to be institutionalized, much more so than is evident today. Our analysis has focused on use of mangroves, a resource that, in spite of the abuse it receives around the world, is appreciated, if not completely understood, in Kosrae (Naylor and Drew 1998). The future of freshwater forested wetlands and upland forests is also threatened, perhaps especially so if harvesting pressure is displaced from mangrove forests. Economic crowding under this scenario would place greater pressure on all of the island's ecosystems. Without cooperative behavior, Kosraeans could effectively eat and chop their resource base from beneath them.

The third scenario is more optimistic and suggests a significant decline in economic crowding. It could also lead to a turning point in migration--defined as the transition from being an exporter of labor in a weak economy to an importer of labor when remittances and incomes are reinvested in the economy.¹⁴ Such a turning point is not on the immediate horizon. Nonetheless, remittances are likely to fuel future investments on Kosrae in the short run, particularly as government sector jobs are eliminated. Whether these investments focus on resource extraction (e.g., crab exports), tourism, agricultural production, other industrial or

¹⁴ See Abella (1994) and related papers in the special issue of *Asian and Pacific Migration Journal* on "Turning Points in Migration" (1994).

service activities, or human capital development remains to be seen, but the outcome could be significant. The most favorable outcome in terms of resource sustainability would be one in which economic growth was based on service-related industries that utilize available labor resources and preserve natural resources. One option might be eco-tourism¹⁵, but other value-added activities that focus on processing or assembling imported materials with domestic labor for export might also be viable.

The next decade will be a critical time to watch the transition in Kosrae, especially in terms of trends in migration, private sector investment, and the use of forest and marine resources. Given the small geographic and population size of the island, a single person or project could have a large and disproportionate impact on the resource base. As a result, village communities and the government of Kosrae will need to decide which path they collectively want to embark upon for future economic development. To achieve societal goals, this effort will require strong institutions and a willingness to limit individual initiatives. Kosraeans no longer live on an isolated island. Their options are open now, yet they will almost certainly be limited unless the emigration outlet remains possible.

¹⁵ This option would be compatible with the preservation of resources only if the human capital/scientific expertise of the population were enhanced and the industry remained at a relatively small-scale given the geographic size of the island.

Appendix A¹⁶

We assume that simple models of exponential growth provide an adequate description of Kosraean population dynamics and use such models to calculate instantaneous rates of migration (m) and population growth (r). The total population, N , comprises the resident population, K , and the expatriate population, E . Because most emigration from Kosrae is temporary and most people living off-island are between the ages of 25-35, we assumed that all population growth stems solely from the resident population on Kosrae. Models for growth of the resident population and the total population over the period from 1994 to 2000 may be written as

$$K_{2000} = K_{1994} e^{(r-m)(2000-1994)} \quad (1a)$$

and

$$N_{2000} = E_{1994} + K_{1994} e^{r(2000-1994)} \quad (1b)$$

respectively, where r is the instantaneous growth rate of the entire Kosraean population, m is the instantaneous (net) migration rate from Kosrae to the expatriate population, and the quantity $(r - m)$ describes the instantaneous growth rate of the resident population. Solving these equations yields

$$1/6 \ln (K_{2000} / K_{1994}) = r - m \quad (2a)$$

and

$$1/6 \ln [(N_{2000} - E_{1994}) / K_{1994}] = r \quad (2b)$$

Substituting the values presented in the text into Equations (2a,b) and solving yields $r = 0.0354$, $m = 0.0174$, and $(r - m) = 0.0182$. To convert these instantaneous rates to equivalent rates for discrete annual intervals, we calculate $R = \exp(r) - 1 = 0.0360$, $M = \exp(m) - 1 = 0.0176$, and $(R - M) = 0.0182$.

¹⁶ The appendix was written with the assistance of Eric Bjorkstedt.

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