

Use Classification of Mangrove Areas, Pohnpei, Federated States of Micronesia¹

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Abstract: An integrated biotic inventory of mangrove areas of Pohnpei, Federated States of Micronesia, was undertaken to determine priority areas for preservation and sustained-yield management. Criteria for the designation of reserve areas included: the presence of threatened or endangered species; rare species or particularly rich biota; undisturbed old-growth communities; the need to maintain intact mangrove to protect biotic resources from excessive wave action or sedimentation; or similarly, to protect cultural and economic resources; areas of high fisheries or forestry productivity; timber stocking, and proximity to wood-consuming businesses or other infrastructure. Standard forest inventory plots consisting of five sample points distributed over 1.4 ha were placed at random throughout the mangrove to describe stand composition and stocking and to estimate the area of mangrove forest exploited and the amounts and types of products removed. Results of studies to date and recommendations for reserves are reported.

At the request of the state government of Pohnpei, one of the four states of the Federated States of Micronesia, an assessment of the mangrove resource on the main island of Pohnpei was undertaken to determine priority areas for preservation and for sustained-yield management. Components of the study included: estimation of the standing volume of mangrove timber by species and size class, assessment of the exploitation of mangrove wood and wildlife products, and estimation of pressure on mangrove areas for uses other than forest. Data on these components and on additional ground and aerial photo surveys have been combined to assign use categories to all mangrove areas. This paper provides an overview of the on-going study and reports preliminary results and recommendations.

Pohnpei is a high volcanic island in the Eastern Caroline Islands (6°54' N, 158°14' E), approximately 4,983 km southwest of Hawaii (fig. 1). It is roughly circular with a diameter of about 23 km and a total area of about 35,488 ha, 16 percent of which is mangrove forest. The mean annual temperature on the coast in Kolonia, the capital, is 27°C, and mean annual rainfall is 4,820 mm. Temperatures vary little, but rainfall shows slight seasonality; January and February are drier than the average month (MacLean and others 1986). The main island of Pohnpei, where this study was done, consists of five municipalities (Nett, Uh, Madolenihmw, Kitti, and Sokehs) plus the capital city.

The vegetation of Pohnpei was described and mapped by MacLean and others (1986). The area of Pohnpei mangrove was estimated to be 5,525 ha, with 5,290 ha capable of commercial timber production. A forest inventory based upon the vegetation mapping estimated that Pohnpei had 403,000 m³ of standing mangrove timber (MacLean and others 1988). Only four plots in

this region-wide inventory were in the Pohnpei mangrove. In order to provide more reliable and detailed estimates of mangrove timber volumes on Pohnpei, an additional study with 77 plots was undertaken. This study (Petteys and others 1986) estimated total mangrove volume at 698,380 m³; it differed from the first study in that measurements were not reduced for poor form or rot, no fixed plot data were included, each plot contained only one rather than five sample points, and the plots were not permanently installed. The second study reduced the estimated area of mangrove timberland to 4,855 ha.

Pohnpei has a significant mangrove timbershed; however, several factors suggest that if conservation measures are not taken now, the best of the resource may be lost. Mangroves are under constant development pressure because they occur in coastal and estuarine areas, also centers of human settlement (Lal 1990). This is true worldwide, but especially so on islands such as Pohnpei where flat land is extremely scarce. Pohnpei's population has grown rapidly since 1950 (fig. 2) and currently has an annual growth rate of around three percent. Because 46 percent of the population was less than 15 years of age in 1985 (Federated States of Micronesia 1988), this growth rate is expected to increase through 2000, even though the fertility rate is declining.

The population grows, and so do individual material expectations. Per capita consumption of manufactured goods such as televisions, video cassette recorders (VCRs), and motor vehicles (fig. 3) continues to increase (Pohnpei State 1990). In the absence of data on Gross National Product, the growth of the general fund of Pohnpei State, which increased from \$12,742,800 in 1984 to \$17,653,800 in 1989, perhaps indicates the accelerating pace of economic activity. More people, consuming and producing more than previous generations, are placing ever-increasing demands on the resource base. Mangrove forests are particularly subject to increased use pressures in the areas of fisheries; timber for construction, furniture, fuel, posts, poles, and other small-dimension lumber and craftwood; and for alternative uses of the land itself. These forests have been and are disturbed by road-building, dredging, waste-dumping and the construction of homes, marinas, and other structures. These uses are expected to intensify with the expanding population and economic activity, especially tourism.

Planning and allocation may enable Pohnpei to conserve representative areas of the mangrove ecosystem, and provide for the sustained production of all commodities traditionally obtained from mangroves. The first objective of this study was to place all mangrove areas into one of three broad use categories: (a) preservation, (b) sustainable use and, (c) general-use areas not specifically reserved for (a) or (b). Criteria in the assignment of use categories were (1) presence of endangered or threatened species, rare species or particularly rich biota, and undisturbed,

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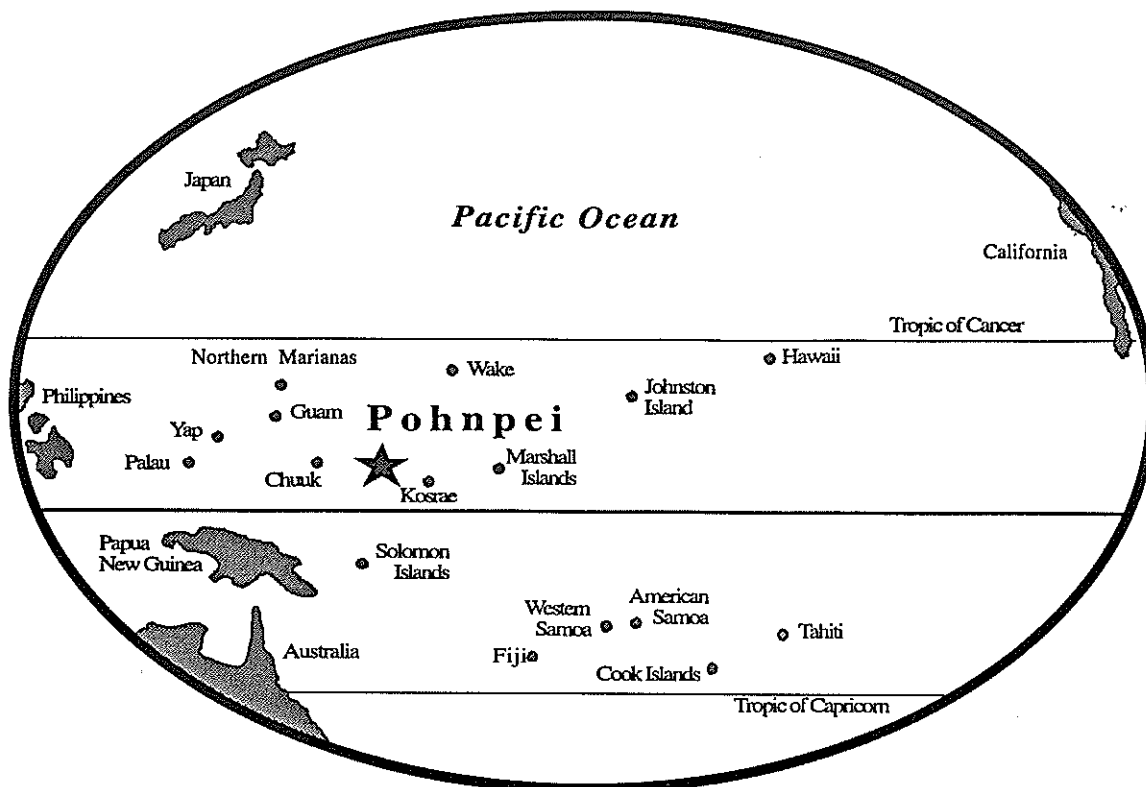


Figure 1—Location of Pohnpei, Federated States of Micronesia. Pohnpei lies at 6°54' north latitude, 158°14' east longitude.

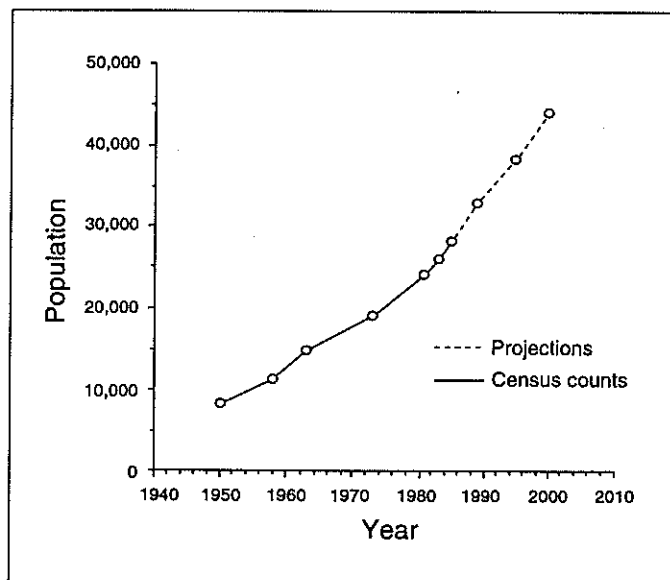


Figure 2—Population of Pohnpei since 1950 (Pohnpei State Government 1986, 1990; Federated States of Micronesia 1988). The projections shown are the lowest from the range given in the Pohnpei State 1985 Census Report (Federated States of Micronesia 1988).

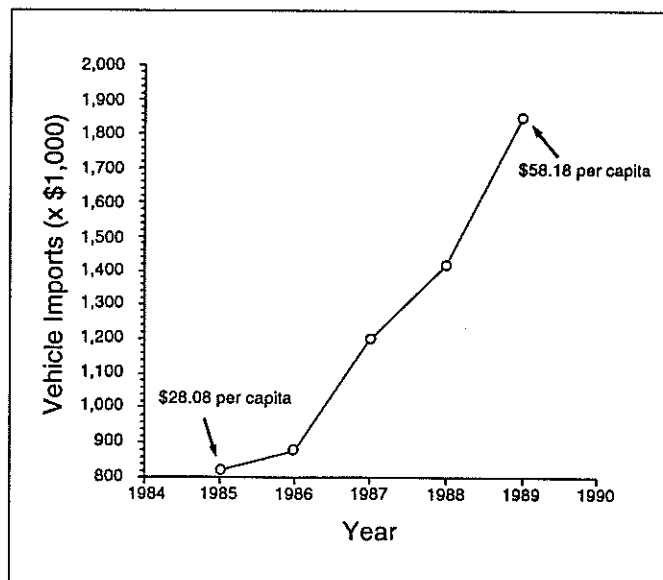


Figure 3—Cost of automobile imports to Pohnpei from Japan and the United States (Pohnpei State Government 1990).

old-growth communities; (2) the need to maintain intact mangrove to protect biotic resources from excessive wave action or sediments, or similarly, to protect cultural and economic resources; (3) presence of fisheries or forests of high productivity, (4) amount of timber stocking and (5) proximity to processing installations and other infrastructure.

Methods

Forest Inventory

The present inventory differs from previous ones in that exploitation is estimated by tallying stumps in addition to standing timber stock; cull is reduced from the volume estimate, and all mangrove areas, even dwarf stands, are included.

Plots were selected on a square grid using a random start. Grid intersections falling within areas mapped as mangrove were selected as field plots. Selected grid points were pinpricked on aerial photographs and located on the ground. Plots were permanently referenced for future remeasurement. For each plot, a cluster of five sample points was established, with the points distributed over approximately 1.4 ha in a standard USDA Forest Service inventory plot (fig. 4). Two samples were taken at each point. The first sample included all trees greater than 2.4 cm and less than 12.5 cm diameter at breast height (d.b.h.) within 2.36 m of point center. The fixed plot sample picked up stocking, growth and regeneration data on smaller trees not measured in the second sample. The second sample was a variable radius plot of all trees within the limiting distance of a metric basal area factor-seven prism (USDA Forest Service 1983).

Species, d.b.h., total height, bark thickness, crown ratio, crown class, azimuth, and distance from point center were re-

corded for all trees. Each tree greater than 12.4 cm d.b.h. was visually divided into logical segments, and end diameters of these segments were measured or estimated. The segments were then classified as either sawtimber, poletimber, craftwood bolts, crotches, branches, or upper stems. Defective segments were identified as cull.

MacLean and others (1986) categorized mangrove stands as either:

MN0—trees of small stature with average d.b.h. less than 12.0 cm,

MN1—trees generally between 12.1 and 30.0 cm d.b.h., or

MN2—trees with average d.b.h. greater than 30.0 cm.

Estimated areas of each of these strata were taken from MacLean and others (1986), thus providing a means of expanding plot data from the per hectare level to the stratum and island level. Data from the field tallies were analyzed with an inventory program developed at the USDA Forest Service Pacific Northwest Research Station. Ground reconnaissance of randomly chosen transects in areas not inventoried was used to assess presence of rare or unusual plant species. Areas identified as old growth from aerial photographs were field-checked.

Timber Cutting Permits and Sawmill Survey

Both the State of Pohnpei and the individual municipalities claim legal authority to regulate mangrove exploitation (relevant legislation outlined in *Appendix*). This jurisdictional dispute aside, municipalities established permit requirements for exploitation, which vary by municipality. Permits were examined to see whether their numbers, types, and costs would provide information on the volume of timber removed, the number of persons involved in exploiting mangrove wood, or the revenues returned to the municipalities from these permits. Another attempt to estimate harvesting independently of the forest inventory was made by canvassing sawmills on Pohnpei.

Demand for Non-forest Use of Mangrove Areas

Land sought for conversion was estimated by reviewing applications for filling and building permits for mangrove areas filed with the Pohnpei State Department of Lands between 1985 and 1991.

Results

Forest Inventory: Standing Timber and Exploited Volume

The inventory was designed to estimate the average stocking (m^3/ha) by stratum within 20 percent of its true value at the 82 percent probability level for the MN1 stratum and at the 95 percent probability level for the MN2 stratum. Based on coefficients of variation derived from the first four plots taken in each stratum (61 percent for the MN1 stratum and 42 percent for the MN2 stratum), 21 plots were required in the MN1 stratum and 17 plots in the MN2 (Dilworth 1970). The results presented here are based only on 7 MN1 and 8 MN2 plots.

Projections of total volume based on these preliminary data (table 1) are about 40 percent higher than values found in the

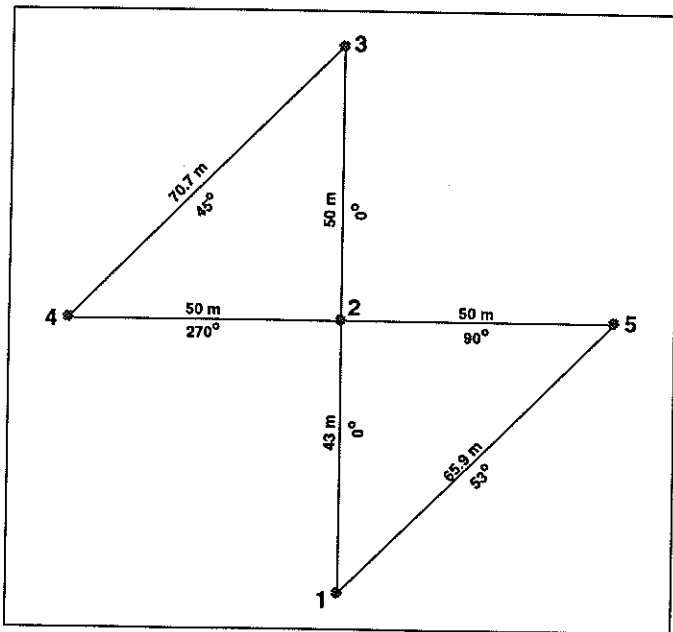


Figure 4—Standard USDA Forest Service plot layout. The sample points are numbered 1, 2, 3, 4, and 5. The distances between the points and the bearings by which they are reached are shown.

Table 1—Mangrove net volume by segment and stratum

Stratum ¹	Roughwood	Sawlog	Bolt	Branch	Pole	Inside bark total	Outside bark total
MN0	3,328	0	0	7,179	32,187	42,713	58,939
MN1	80,434	62,235	26,636	30,010	125,292	324,716	418,429
MN2	104,830	326,843	25,298	35,858	95,527	588,269	703,539
Total	188,592	389,078	51,934	73,047	253,006	955,698	1,180,905

¹ MN0 Trees of small stature with average diameter at breast height (dbh) less than 12.0 cm

MN1 Trees generally between 12.1 and 30.0 cm dbh

MN2 Trees with average dbh greater than 30.0 cm

previous inventory (Petty and others 1986). This is probably due to a bias created by the order in which the plots in this study were installed. Because the first objective was to evaluate areas already identified from other reconnaissance as having the highest values for preservation and management, the plots that fell in these areas were installed first. No conclusions can be drawn from these data until the entire sample is taken.

However, these data do suggest some noteworthy trends. The range of volumes per hectare is larger than previously thought, with more variation in site quality and stand response than has been noted before or elsewhere in mangroves. Although stem dimensions are generally quite small, the MN0

stratum is densely stocked and standing basal area is nearly the same as that in the MN1 stratum. Useful products do come from the dwarf mangrove (table 2), and among other things, it represents a significant carbon store.

Species tallied were (nomenclature after Fosberg and others 1979):

<i>Bruguiera gymnorhiza</i> (L.) Lam.	Rhizophoraceae
<i>Lumnitzera littorea</i> (Jack) Voigt	Combretaceae
<i>Rhizophora apiculata</i> Bl.	Rhizophoraceae
<i>Rhizophora mucronata</i> Lam.	Rhizophoraceae
<i>Sonneratia alba</i> J.E. Smith	Sonneratiaceae
<i>Xylocarpus granatum</i> Koen	Meliaceae
<i>Heritiera littoralis</i> Dryand	Sterculiaceae

Table 2—Average net volume in m³ and international board feet (IBF), quadratic mean diameter (QMD), and basal area per hectare (BAPH) by stratum and species

Species ¹	Inside bark						Outside bark		QMD cm	BAPH m ² /ha	Stump BAPH m ² /ha	
	Roughwood	Sawlog	Bolt	Branch	Pole	Total	Total	IBF				
				m ³								
Stratum MN0												
BR GY	.0	.0	.0	.0	.0	.0	.0	.0	.00	.11	.00	
LU LI	6.1	.0	.0	11.4	53.9	71.4	101.5	.0	16.70	22.92	4.48	
RH AP	.6	.0	.0	3.0	10.7	14.4	16.8	.0	14.49	4.14	.00	
RH MU	.0	.0	.0	.0	.0	.0	.0	.0	.00	1.78	.00	
SO AL	.0	.0	.0	.0	.0	.0	.0	.0	.00	2.15	.00	
Total	6.7	.0	.0	14.4	64.6	85.8	118.4	.0	16.41	31.10	4.48	
Stratum MN1												
BR GY	8.0	6.3	1.5	5.2	21.6	42.8	61.0	872.3	21.62	12.98	.73	
RH AP	1.8	4.0	.0	.8	19.9	26.5	35.2	559.7	20.47	6.36	.00	
RH MU	1.2	.0	.3	.4	7.6	9.4	13.2	.0	16.71	3.25	.00	
SO AL	8.8	11.9	.5	.9	5.2	27.2	33.6	1,715.8	32.92	4.90	.00	
XY GR	13.6	1.6	6.7	3.3	7.9	33.1	6.7	193.2	21.13	5.22	.23	
Total	33.3	23.7	9.0	10.6	62.3	138.9	179.7	3,341.0	21.72	32.71	.96	
Stratum MN2												
BR GY	14.8	23.9	.8	4.2	12.5	56.2	73.1	3,380.8	28.14	10.69	.35	
HE LI	.0	.0	.0	.1	1.3	1.4	1.5	.0	.00	.31	.00	
RH AP	6.3	22.2	1.0	2.9	11.8	44.3	52.8	3,527.0	27.98	5.41	.17	
RH MU	2.3	.8	.0	.8	5.6	9.3	12.1	33.7	20.32	2.09	.00	
SO AL	14.5	52.4	4.8	3.1	1.3	76.1	88.9	7,540.6	59.65	10.32	.00	
XY GR	8.5	33.5	3.4	3.0	3.7	52.1	57.1	4,715.5	44.44	6.87	1.95	
Total	46.4	132.8	10.1	14.0	36.2	239.5	285.6	19,197.5	33.99	35.69	2.47	

¹ BR GY = *Bruguiera gymnorhiza*; LU LI = *Lumnitzera littorea*; RH AP = *Rhizophora apiculata*; RH MU = *Rhizophora mucronata*; SO AL = *Sonneratia alba*; HE LI = *Heritiera littoralis*; XY GR = *Xylocarpus granatum*.

Heritiera littoralis is found in the transition zone between the agroforest or lowland forest and the mangrove; the others are true mangrove species occurring only in the mangrove.

The species with the majority of volume varies by stratum (table 2). The volume summations are only for growing stock trees, which have d.b.h. greater than 12.4 cm. The results for the MN0 stratum are thereby distorted, because the very small but numerous stems of *Rhizophora mucronata* and *R. apiculata* do not enter the calculation. *Lumnitzera littorea* dominated because only the largest trees were considered; *R. apiculata* followed. *Lumnitzera littorea* was found in this sample only in stratum MN0. The species occurs outside the dwarf mangrove, but most of the large dimension *Lumnitzera*, Pohnpei's most valuable mangrove species, has been logged. None of the inventory plots fell in the cut-over areas. Replacing this population and stewarding what is left are high priorities for the Pohnpei forest management program. In the MN1 stratum, *Bruguiera gymnorhiza* had the highest volume. In the MN2 stratum, *Sonneratia alba* predominated.

As can be seen in table 2, *Lumnitzera littorea* is harvested even as small stems. Commercial harvesting accounted for most of the exploited volume, with stump basal area nearly 20 percent of the standing basal area/ha. Stump basal area/ha was 28 percent of standing basal area/ha for *Xylocarpus granatum* in the largest size classes. *Xylocarpus granatum* is a high-value wood; branchwood is carved into handicrafts while larger stems are sawn for cabinetry, flooring, and other interior construction. Harvesting in the pole timber sizes was mostly *Bruguiera gymnorhiza* (stump basal area/ha about six percent of standing basal area/ha) and *Rhizophora apiculata* (stump basal area/ha approximately three percent of standing basal area/ha). Cutting of these species as pole-sized stems is almost certainly subsistence extraction for house timbers. Smaller stems of these species are also taken on a subsistence basis for uses such as fence posts.

Timber Cutting Permits and Sawmill Survey

Kolonia does not regulate mangrove exploitation. Uh kept no records. Madolenihmw had eight records on file for the period February 1987 through January 1991 for which a total of \$634 was collected, \$500 of which was a permit for a commercial sawmill. By contrast, Nett had 10 records on file for the period October 1990 through February 1991 for which a total of \$10 was collected. Kitti had 48 records on file for the period August 1990 through May 1991. Five of these 48 records were from persons who had already held at least one permit. Kitti records included the location of the requested harvest; the number of days for which the permit was valid; and for 10 of the records, the number of trees taken. These 10 records summed to 1,240 trees. Two hundred dollars was collected; most of the permittees were not charged. Only two of the permit requests filed in Kitti could be for commercial purposes (the data are not explicit), and these are for 100 trees or less. It is often said but not documented that virtually all the mangrove timber now being sawn on Pohnpei is coming from Kitti; the implication is that the municipality is not capturing all the revenue to which it is entitled.

Sokehs had 384 permit applications on file for the period October 1985 through March 1991; these generated \$1419 for the municipality. There were two gaps in the holdings, the last months of 1989 and February-May 1990. The records indicate that most of the exploitation in Sokehs is by woodcarvers from Kolonia who sell their handicrafts to tourists. Firewood cutting was a close second, most of the requestors also residing in Kolonia. Approximately 50 percent of the permit applications filed during this period were from persons who had already held at least one permit. Because of proximity to Kolonia, activity in Sokehs cannot be taken as representative of the whole of Pohnpei. The Sokehs permits allow unlimited cutting for three days, so it is unknown what wood volume they represent.

Records from defunct sawmills were unavailable. Among operating mills, only one acknowledged that records of sawn volume were kept. This mill was involved in building a controversial tourist facility and so refused to disclose any records. In the course of the canvassing, it was learned that the first sawmill began operation on Pohnpei in 1942. In 1952, a second mill started up and both operated through 1972. One closed and two new ones were established in 1973; three mills were sawing through 1975. In 1976, one of the mills started in 1973 closed. By 1985, four mills were operating, one intermittently. Two closed the following year. A new mill opened in 1988, and three mills have continued to function, two intermittently, since then. It is noteworthy that so few permits for commercial milling are on file while three mills are operating on this small island. Other wood-consumers include furniture makers and a soap factory; I have no estimates of their consumption.

Demand for Non-forest Use of Mangrove Areas

From 1985 through 1990, at least 62 applications for development of mangrove areas were filed with Pohnpei State Department of Lands (table 3). Because of the disorder of the records and gaps in the holdings, these data appeared incomplete. Of the 62 permit requests on file, 57 were granted. Most of the requests were for the filling of the swamp and building or expansion of residential facilities on what is legally public land. Only three public works projects were officially sited in the mangrove. Of the 57 approved applications, 13 were for unspecified amounts of land. The total area explicitly approved for conversion was approximately 10 ha; the actual amount may have been much higher. Most of the requests on file were from municipalities with the least land; Uh with 24 percent of the permit applications, 6 percent of the total land area, and 9 percent of the population; and Sokehs with 47 percent of the permit applications, 12 percent of the land area and 18 percent of the population (Pohnpei State 1986). Much of the land in Sokehs is too steep for any form of development.

Data from building and filling permits are too sketchy to reflect actual land use pressure. Viewed from the circumferential road, recent encroachment appears to be considerably greater than 10 ha. Mangroves are a popular location for piggeries and outhouses, presumably because tides flush the areas. In addition to the existing, unpermitted conversion, there are plans afoot for developments that would destroy extensive mangrove tracts. One of these is a 500-bedroom hotel proposed for Nett.

Table 3—Applications for filling and building in mangrove forest filed with the Pohnpei State Department of Lands 1985-1990

Municipality	Applica- tions denied	Area in each (total) m ²	Applica- tions approved	Area in each (total) m ²	Total area approved for conversion ha
Uh	None	0	11 Resi ¹ 1 Resi 2 Comm 1 Public	50,454 unspec 4,500 334	5.53 plus unspec
Sokehs	2 Resi	745	20 Resi 4 Resi 2 Comm 1 Public	20,967 unspec 711 4,500	2.60 plus unspec
Nett	1 Comm	7,607	1 Resi 1 Public	2,500 2,322	0.48
Madolenihmw	None	0	3 Resi 3 Resi	1,620 unspec	0.16 plus unspec
Kitti	None	0	None	0	0
Kolonia	2 Resi	1,640	1 Resi 5 Resi 1 Public	520 unspec 7,333	0.78 plus unspec

¹Resi = Residential, Comm = Commercial, unspec = unspecified

I continue to measure (through sampling) current and past exploitation in the mangrove as one estimate of the demands on the resource. Since some desired uses will have been frustrated (i.e., cutting and building permit requests that were discouraged before an application was filed), demand must be underestimated. I anticipate that increasing demand will at least parallel expanding population; probably, demand will accelerate faster than population due to increased economic activity.

Discussion

Holthus (1987) listed the prohibition of clear cutting on the lagoon side of mangrove forests and in areas where the mangrove strip is less than 250 m wide as the highest priority management intervention for the protection of coastal resources. Ecological services of mangroves include: protection of coastline and infrastructure from the action of wind and waves; filtration of upland sediment, thereby protecting lagoon and reef systems; critical habitat for larval and juvenile fish; habitat for other wildlife, especially birds, and conservation of germplasm.

Preservation and conservation measures are necessary now. While the filling and building permit applications suggest that little mangrove is legally converted to other uses, field reconnaissance indicates that the active degradation of mangrove is extensive. Known clearcuts apart from those for development total only about 150 ha, but of all the mangrove covered on foot during 1990 and 1991, not a single site was without evident harvesting.

According to the US Fish and Wildlife Service (Herbst and Engbring 1991), no plant species are listed as threatened or endangered from the Pohnpei mangrove, nor are the mangroves critical habitat for any threatened or endangered species. However, old-growth stands are prime habitat for a number of sea-birds and for the fruit bat (*Pteropus mariannus*). The USDA Forest Service recently sponsored a study of epiphytes in the mangrove that found a number of taxa not previously described; it is not yet known how widespread these are. For the tree component, there are no rare species or unusual assemblages in the Pohnpei mangrove. The remaining criteria for assigning use categories (see Introduction) remained operational at the close of this assessment.

Recommended Sites for Preservation and Management

The following categories are proposed to designate reserve areas:

- A. Preserve: access severely restricted. Uses limited to protective functions, wildlife habitat, and non-manipulative research.
- B. Sustainable Use: Class 1 Parks. Access unlimited, activities restricted; No timber harvesting; hunting and fishing by permit only.
- B. Sustainable Use: Class 2 Demonstration and Production Forest. Access unlimited, activities restricted. Forest management to be conducted by Pohnpei State Division of Forestry; harvesting of marked timber by permit (subsistence) or concession (commercial) granted by the Division of Forestry; hunting and fishing by permit only.

A well-designed reserve system generally includes core areas that are strict nature preserves where no anthropocentric influence is allowed. Surrounding core areas are zones designated for uses of varying intensities, with the least intensive uses contiguous with the core area.

The following 11 sites, totalling 1915 ha or 35 percent of the total mangrove area, are suggested as those most important to include (fig. 5). Category A accounts for 434 ha, category B1 for 176 ha, and category B2 for 1305 ha. The area within either preserves or reserves is limited to what can optimistically be protected and in some cases, managed, to maximize benefits to society. The features referred to below can be seen clearly on the U.S. Geological Survey 1:25,000 topographic maps of Pohnpei (U.S. Geological Survey 1983).

1. *Dausokele, Nett*. Category A. 30 ha MN2, 18.5 ha MN1. This reserve should include all land along the Dausokele, especially the area south of the circumferential road and north of Pilen Sepei. This area is sought primarily for maintenance of aquatic habitat and water quality. The mangrove also protects an important taro cultivation area.

2. *Parempai Island, Nett*. Category A. 20 ha MN2, 26 ha MN1/0; Category B2. 41 ha MN1/0. The core area contains some of the oldest and least disturbed dwarf and MN1 mangrove on Pohnpei; the production forest borders it on the south. The reserve is desired to preserve this valuable community and to

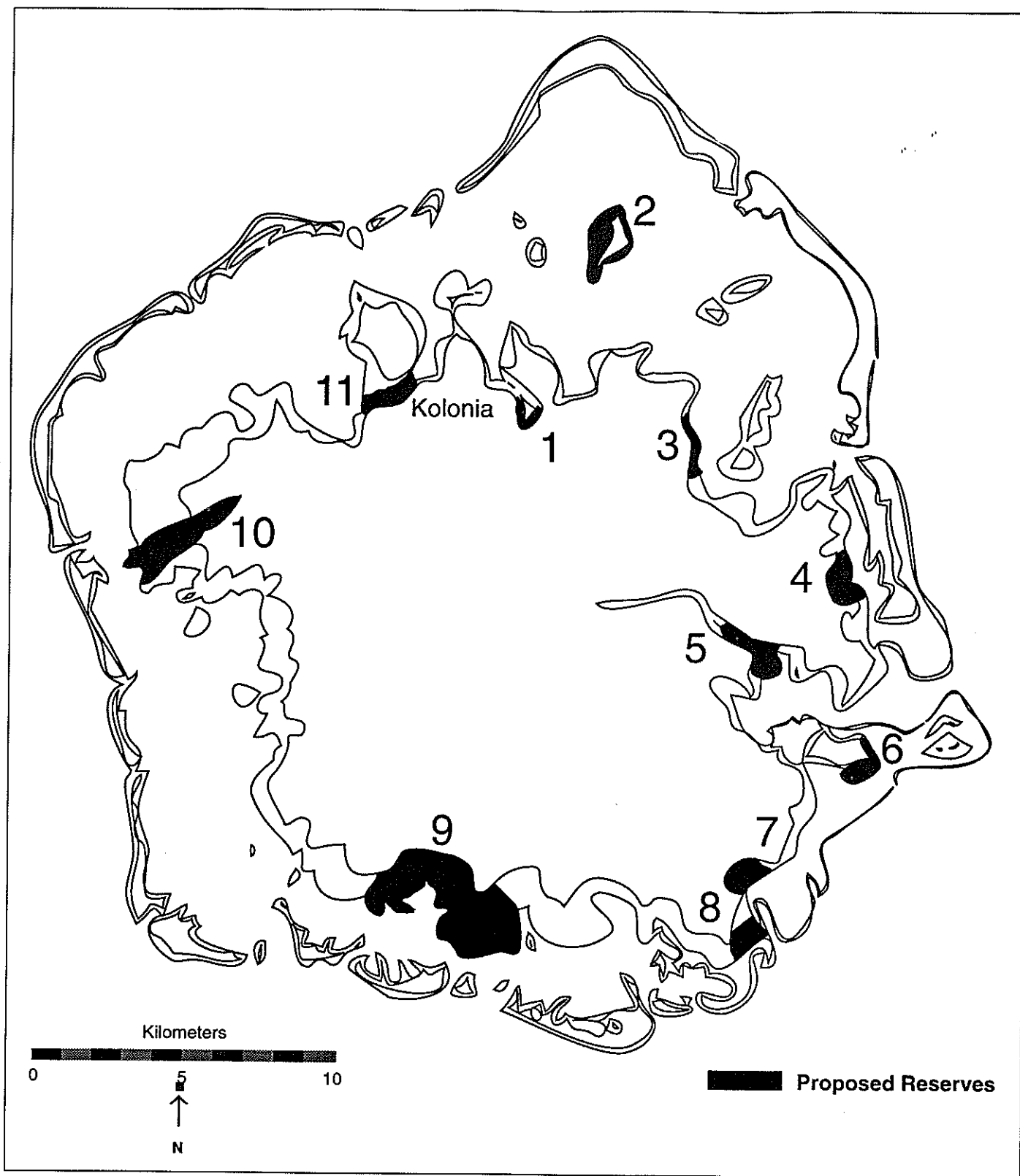


Figure 5—Darkened areas represent proposed mangrove reserves, Pohnpei, Federated States of Micronesia: (1) Dausokele, Nett; (2) Parempai Island, Nett; (3) from Nansalohi to channel north of Maramosok, Uh; (4) from the Lamahi to the Dien Outcrop, Madolenihmw; (5) Dauen Sapwalap, Madolenihmw; (6) Nan Madol, Madolenihmw; (7) land be-

tween Pilen Kihlid/Dauen Wapar and Dauen Lohd, Madolenihmw; (8) land between Kepindau Pohnahtik and Nan Diadi, Madolenihmw; (9) land between Dauen Semwei and Dauen Rakis, Enpein, Kitt; (10) Dauen Soundau, Sokehs; and (11) Dau Mwoakote, Sokehs. The island is surrounded by a barrier reef.

safeguard the health of Parempei Island's fringing reef and the barrier reef surrounding Pohnpei. The interior of Parempei is high and extremely steep, especially on the north side; without complete mangrove cover, water-borne sediments would quickly silt the near-shore corals. Parempei and surrounding waters were proposed as a marine park (Holthus 1987) and described as especially rich in octopus (U.S. Army Corps of Engineers 1985).

The production forest is necessary to provide for the material needs of the small Parempei Island population. If the reserve is well-managed, all the house timbers, posts, and poles required can be supplied from a relatively small area. Parempei would be an excellent site to begin intensive forest management because of the small user population, absence of commercial use pressure, and relative ease of controlling access.

3. *From Nansalohi to channel north of Maramosok, Uh.* Category A. 42 ha MN2. A considerable volume of fresh water of upland origin drains through this mangrove through two rivers and a host of smaller streams. Water moves from the extreme slopes of the crest at the Nett-Uh boundary at high velocities during storm events. Because vegetation has been greatly reduced on the east-facing slopes, the sediment load is probably high. This mangrove should be preserved to protect water quality. The forest has been "picked over" for various products but is a well-developed old-growth area interesting in its own right. U.S. Army Corps of Engineers (1985) identified this area as important habitat for the mangrove crab. Much of the mangrove on the lagoon side of the circumferential road through Uh has been severely degraded; it is recommended that action be taken immediately to protect this section.

4. *From the Lamahi to the Dien Outcrop, Madolenihmw.* Category A. 44.5 ha MN2; Category B2. 57 ha MN1, 17 ha MN0. This preserve area is sought for some of least-disturbed old-growth MN2 on the eastern side of Pohnpei, with a management area to surround and buffer the core area. Forest manipulation should be confined to the landward side of the reserve in order to protect a highly productive reef fishery; this area was also identified as important habitat for the mangrove crab (U.S. Army Corps of Engineers 1985). Low use pressure in the locale suggests that this reserve should be relatively easy to protect. Some timber of suitable dimensions might be available from this reserve to feed the two sawmills in Nett.

5. *Dauen Sapwalap, Madolenihmw.* Category A. 30 ha MN2, Category B2. 43 ha MN1. Much of this area was logged during the Japanese era; the best and least-accessible stands should be preserved in a core area. The tallest and largest mangrove on the island is here. High forest productivity is inferred from the existing stand, topography, and substrate. The reserve should be between the mouth of the Sekerieriau and Wetiak channels, easy features to find on the ground. This reserve could contribute feedstock to the mills in Nett and to the Ponape Coconut Products soap factory (thinnings).

6. *Nan Madol, Madolenihmw.* Category B1. 13 ha. Nan Madol is perhaps the premier archeological site in the western Pacific. Much of the mangrove near the ruins on Temwen has been cleared for gardening and house lots; the vegetation on the small islands of the ruins themselves has been extensively modified. The site should receive special legal status, probably as a

State Park, to maintain the character of the area and to protect the ruins. Restoration and conservation of the mangrove would protect the reef fishery and lobster habitat (U.S. Army Corps of Engineers 1985) at the nearby reef passage. Holthus (1987) recommended that this area be a species preserve for top shell (*Trochus*), giant clams (*Tridacna*), and lobster (*Panulirus*). My recent examination disclosed that the reef nearest Nan Madol has been highly disturbed.

7. *Land between Pilen Kihlid/Dauen Wapar and Dauen Lohd, Madolenihmw.* Category B2. 29.5 ha MN2, 8.1 ha MN1. One of the few areas known where large *Lumnitzera littorea* occurs. One section was logged in 1988 with an appalling waste of wood; another part was logged earlier and regeneration is lacking in both areas. The clearcuts should be regenerated with slash reduction and tests of seed bed and light level effects on germination and establishment of *lumnitzera*. Large-dimension thinnings and products of limited selection harvesting could feed the Kitti and Nett mills from this reserve. The channel has a deep silt bed, and silt deposits are found out toward the reef (U.S. Army Corps of Engineers 1985). Tree cover should be restored and manipulated on the landward side only, with selection and shelterwood cuttings to minimize soil exposure. Highly productive reef fisheries, sea grass beds, fish aggregation areas, and fish migration routes are found at the mouth of the channel (U.S. Army Corps of Engineers 1985).

8. *Land between Kepindau Pohnahtik and Nan Diadi, Madolenihmw.* Category B2. 22.5 ha MN2, 50 ha MN1, 4.9 ha MN0. This area carries the highest timber volume in the Pohnpei mangrove. Logging of *Lumnitzera littorea* took place in the central portion of the parcel. This reserve is sought for management, research, and demonstration primarily because of its productive capacity and the occurrence of stands in many developmental stages within a small area. Timber for the Kitti mill could come from here. Forest manipulation should be confined to low-intensity operations on the landward side to prevent siltation of the sea grass beds, which are known sea turtle feeding areas. Mangrove crab is abundant; a rich reef fishery, fish migration route, lobster and lipwei (*Anandara antiquata*) clam beds are also found (U.S. Army Corps of Engineers 1985). Holthus (1987) proposed this area as a species preserve for trochus, giant clams, and lobster.

9. *Land between the Dauen Semwei and Dauen Rakis, Enpein, Kitti.* Category A. 76 ha MN2; Category B1. 83 ha MN2, 80 ha MN1 (plus lagoon areas); Category B2. 151 ha MN2, 230 ha MN1, 135 ha MN0. (Total area 755 ha). The primary factor indicating desirability of a reserve in this area is the need to trap sediments carried by the major drainages in the locale. Deep sediments line the channel (U.S. Army Corps of Engineers 1985). A concentration of known sea turtle feeding and nesting sites are found in this area, the reef complex is especially rich in lobster and trochus, and the forest contains abundant mangrove crab (U.S. Army Corps of Engineers 1985). In addition, some of the forest is particularly well-developed and contains the now scarce *Lumnitzera littorea*. The truly majestic and little modified mangrove has mostly been placed in Category A.

The Category B1 area includes the canoe landing and waterways presently used by the Enpein Marine Park (EMP) Corporation for their ecotourism enterprise. Considerable backing has been amassed for legally constituting this area a State or National Park; this would have social as well as conservation benefits. The condition of the forest visible along the canoe route is surprisingly good, considering that there is effectively no control on exploitation. The area is exploited by locals for a range of materials and foodstuffs. Except for the cutting done by the Enpein Marine Park Corporation itself, the exploitation has been low impact. The best mangrove is to the west of the canoe landing, not at present part of the park tour. However, within the western section of the park tract there is also a clearcut of perhaps 8 ha. The clearcut should be treated as a B2 inclusion, rehabilitated, and used to study regeneration of *Lumnitzera littorea*. The park should extend to and include the reef.

The land immediately west of the Dauen Semwei is proposed as a research and management location. While the landward end of the peninsula between the Semwei and Enpein Pah is mostly old-growth forest, it has been heavily exploited by commercial timber interests, and because of accessibility via an extensive channel network, is now heavily exploited by locals for smaller timbers (poles, posts, canoe wood, fuel, etc.). The west central area of this peninsula is dwarf mangrove. Land to the west of Dauen Pakein and east of Dauen Rakis is also a proposed management area. Some of this is important wildlife habitat; some is well-stocked pole timber that would be excellent for study of response to thinning and other silvicultural intervention, and some is dwarf and MN1 that is included to protect the marine environment, shoreline, and the interior forest. Subsistence and mill timbers can be produced. Holthus (1987) proposed a marine park for the area west of the Dauen Rakis.

10. *Dauen Soundau, Sokehs*. Category A. 50 ha freshwater swamp, 21 ha MN2, 19 ha MN1; Category B1/2. 387 ha MN1, 83 ha MN0 (Total 560 ha). Much of the land interior to and elevated above this large drainage has been under agriculture since the Japanese era. The mangrove should be given special status to safeguard water quality; the river bed is deeply silted. A reserve here is also desired to protect the unique freshwater swamp community within. The larger reserve may have some potential as a park; the market for this park would be the community associated with Federated States of Micronesia government functions at Palikir. The B2 lands could also be managed in time to feed the small-dimension lumber market centered on Kolonia, which is now consuming Sokehs mangrove further east. Mangrove crab populations were reported to be high immediately north and south of the Soundau (U.S. Army Corps of Engineers 1985). Holthus (1987) proposed a marine park for the reef complex off the Soundau, which includes small mangrove islets reported to be important sea bird nesting sites.

11. *Dau Mwoakote, Sokehs*. Category A. 56 ha MN2; Category B1/2. 45 ha MN1. A reserve is needed here to protect the banks of this fast-moving channel and to reduce the movement of pollutants from Kolonia into Sokehs Harbor. South of the channel there is some excellent old-growth mangrove which has been little disturbed. At the west end of the channel are sea grass and lipwei clam beds and an important reef fishery (U.S.

Army Corps of Engineers 1985). Because the channel and surrounding forest are beautiful and close to both Kolonia and Palikir, this reserve may have some potential as a park.

I foresee serious problems with the acceptance of designated reserves of any description on the part of elected officials and the general public unless well-structured public education is undertaken now. People need to understand what the costs and benefits of reserves will be and how these will be equitably distributed. In order to successfully implement a reserve system, appropriate legislation conferring special legal status upon these areas is necessary. The authority to enforce this legislation, a budget sufficient to execute demarcation, management and protection of the reserves, and additional skilled professionals to carry through the program with dedication and vision are all requisite to success.

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Appendix: Legislation Relating to Mangrove Use

Under the Trust Territory government, Public Law 104-67 gave municipalities the right to tax and regulate the use of mangrove and upland forest. Each of the municipalities except Kolonia passed laws to this effect, beginning with Uh and Kitti in 1961. In 1979, the State of Pohnpei passed the Forest Management Act (D.L. No. 4L-203-79), transferring jurisdiction over lands below the high tide mark to State government agencies. Another state law, the Pohnpei Watershed Forest Reserve and Mangrove Protection Act (L.B. 381-85), was passed in 1987. This act was intended to restrict cutting, dredging, building, and polluting in mangrove areas upon the filing of regulations to accompany the law. The regulations have yet to be signed into law. The municipalities in some cases revised their earlier legislation but without recognizing the state authority. The present situation is that State agencies maintain that only they have the authority to permit or restrict exploitation in the mangrove, while the municipalities also claim this authority.

Uh passed a law in 1961 (Uh Municipal Ordinance 5-61) that levied a charge of \$1.00 for the cutting of any tree larger than 30.5 cm (12 inches) d.b.h.. This legislation has not been revised. It appears that the law is not enforced; no records indicating revenues collected were located.

Kitti also passed a law in 1961 (*Kitti Municipal Ordinance 5-61*) that taxed residents \$1.00 per year for the exploitation of mangrove and upland forest trees. Sawmills were required to pay a \$10-per-year license fee.

Kitti Ordinance 5-61 was superseded by *Kitti Law 2I-96-90* in 1990. No permit or tax is now required of *Kitti* residents cutting for their own consumption, and religious and municipal government agencies are exempted from permit requirements provided that harvested timber be used "for the benefit of *Kitti Municipality* or the religious organization." Harvesting for commercial purposes requires a \$50.00 permit fee, plus cutting fees of \$150.00 for every 50 trees greater than 10 cm (4 inches) diameter at the base, and \$50 for every 100 trees with basal diameter smaller than 10 cm that are taken.

Madolenihmw's 1969 law charged a \$1.00 cutting fee for up to 300 trees up to 28 cm (11 inches) basal diameter taken for personal use. Additional trees required additional permits. The fee charged for each tree taken for canoe or boat-making was \$3.00; for each tree greater than 28 cm basal diameter processed in a sawmill or for personal use, \$3.00; and for each tree up to 28 cm basal diameter taken for commercial use, \$1.00. The law stipulated that mangrove trees not be cut from the ocean side of the swamp.

The *Madolenihmw* law was revised in 1990 (*MB 10-90*). A \$5.00 permit fee is charged to harvest an unlimited number of trees for personal use during one day at one location; \$100.00 is charged for commercial permits under the same conditions.

Nett passed its first ordinance governing mangrove exploitation in 1978 (*Nett Municipal Ordinance 11-78*). This law required anyone seeking a cutting permit to pay a \$1.00 application fee. In 1991, a commercial cutting license fee of \$500.00 was added (*Nett District Law 73-91*).

Sokehs passed a law in 1971 (*Sokehs Municipal Ordinance 1-71*) levying the following charges for cutting trees for personal use:

- \$0.25 per tree, up to 50 trees, up to 7.5 cm (3 inches) basal diameter
- \$0.50 per tree, up to 50 trees, 7.5-15 cm basal diameter
- \$1.00 per tree, 15-28 cm basal diameter, or smaller if processed in a sawmill,
- \$1.50 per tree for trees 28 cm and larger basal diameter
- \$2.50 per tree for any tree 28 cm or larger in basal diameter used for carving a canoe

Trees cut and removed for commercial uses or for the construction of any business facility were charged:

- \$0.30 per tree for any tree 10 cm or less in basal diameter
- \$0.50 per tree for any tree 10 cm or less in basal diameter processed in a sawmill
- \$1.00 per tree for any tree 10-28 cm basal diameter
- \$3.00 per tree for any tree greater than 28 cm basal diameter.

Only twisted, gnarled or dead trees could be taken for firewood. *Sokehs* passed a new law in 1986 (*Sokehs Municipal Law SC1-40-86*) that revised these fees:

- \$2.50 for cutting house timbers
- \$2.00 for firewood for personal use, \$5.00 if firewood is to be sold

\$10.00 for harvest of wood for handicraft production or "other related businesses"

\$50.00 for harvesting for a commercial sawmill

\$5.00 for harvesting for any purpose not included above.

These permits place no restrictions on volume, and are valid for up to three days after being signed.

Kolonia has no laws relating to mangrove exploitation. According to the mayor, "There are not enough mangroves to worry about." In fact, there are about 50 ha of good mangrove within *Kolonia* that have not been eradicated due to limited accessibility.

References

- Dilworth, J.R. 1970. Log scaling and timber cruising. Corvallis, OR: OSU Bookstores, Inc.; 466 p.
- Federated States of Micronesia. 1988. Pohnpei State 1985 census report. *Kolonia*, Pohnpei State, Eastern Caroline Islands: Federated States of Micronesia Division of Statistics, Office of Planning and Statistics; 123 + iv p.
- Fosberg, F.R.; Sachet, Marie-Helene; Oliver, Royce. 1979. A geographical checklist of the Micronesian Dicotyledonae. *Micronesica* 15 (1 and 2): 41-295.
- Herbst, Darrell; Engbring, John. 1991. Biologists, U.S. Fish and Wildlife Service, Honolulu. [Telephone conversation with Nora N. Devoe].
- Holthus, Paul F. 1987. Pohnpei coastal resources: proposed management plan. Draft report. Noumea, New Caledonia: South Pacific Regional Environmental Programme, South Pacific Commission; 101 p.
- Lal, Padma N. 1990. Conservation or conversion of mangroves in Fiji. An ecological economic analysis. Occasional Paper No. 11. Honolulu, HI: Environment and Policy Institute, East-West Center; 108 p.
- MacLean, Colin D.; Cole, Thomas G.; Whitesell, Craig D.; Falanruw, Marjorie V.; Ambacher, Alan H. 1986. Vegetation survey of Pohnpei, Federated States of Micronesia. Resource Bulletin PSW-18. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 9 p. + 11 maps.
- MacLean, Colin D.; Whitesell, Craig D.; Cole, Thomas G.; McDuffie, Katharine E. 1988. Timber resources of Kosrae, Pohnpei, Truk, and Yap, Federated States of Micronesia. Resource Bulletin PSW-24. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 8 p.
- Petteys, Edward Q.P.; Peter, Salis; Rugg, Raymond; Cole, Thomas G. 1986. Timber volumes in the mangrove forests of Pohnpei, Federated States of Micronesia. Resource Bulletin PSW-19. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture; 2 p.
- Pohnpei State Government. 1986. Economic and social statistics of Pohnpei State. *Kolonia*, Pohnpei, Eastern Caroline Islands: Division of Economic Planning, Department of Conservation and Resources Surveillance, Pohnpei State Government; 30 p.
- Pohnpei State Government. 1989. Pohnpei State statistics. Yearbook 1989. *Kolonia*, Pohnpei, Eastern Caroline Islands: Office of Budget, Planning and Statistics, Pohnpei State Government; 152 p.
- Pohnpei State Government. 1990. Pohnpei State statistics. Yearbook 1990. *Kolonia*, Pohnpei, Eastern Caroline Islands: Office of Budget, Planning and Statistics, Pohnpei State Government; 161 p.
- U.S. Army Corps of Engineers, Pacific Ocean Division. 1985. Pohnpei Coastal Resource Atlas. Honolulu, HI: Manoa Mapworks; 78 p.
- U.S. Department of Agriculture, Forest Service. 1983. Field manual for the forest inventory of the Federated States of Micronesia, Kosrae, Ponape, Truk, Yap. Unpublished. Available from Pacific Northwest Forest Experiment Station, Forest Service, U.S. Department of Agriculture, Portland, Oregon; 24 p.
- U.S. Geological Survey. 1983. Island of Ponape (North Half) and Island of Ponape (South Half) 1:25,000 topographic maps. Denver, CO: U.S. Geological Survey, Department of the Interior; 2 leaves.