Pacific Science (1977), vol. 31, no. 4

Vegetation and Urbanization on Majuro Atoll, Marshall Islands[1]

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ABSTRACT: The urban and nonurban vegetation on the Micronesian atoll of Majuro is described, including changes in forest canopy, understory shrubs, yards, and cultural features since urbanization began in 1944. Currently, the nonurban areas are covered with *Cocos nucifera* (coconut) groves mixed with smaller *Artocarpus altilis* (breadfruit) groves, which were probably established in the late 1800s. Indigenous vegetation is limited to a narrow band along the ocean or lagoon shoreline, or as minor understory species in the *Cocos–Artocarpus* groves. A United States military base was established in 1944 on three eastern islands of the atoll (Uliga, Dalap, and Djarrit). This has subsequently been developed into a major administrative and commercial center for the Marshall Islands. Urbanization on Uliga, Dalap, and Djarrit has resulted in reduction of tree canopy; establishment of extensive yards with grasses, herbs, and sedges; and reduction of many indigenous and aboriginally introduced understory species. Nevertheless, some aboriginally introduced and indigenous species remain in the urban areas as important species (*Cocos*, *Artocarpus*, and *Tournefortia*), with many being actively propagated. Ornamental species, which have expanded in importance, especially in the shrub layer, consist primarily of species recorded in Laura village prior to urbanization. The urban plant community is a mixture of indigenous, aboriginally introduced, and recently introduced species. Future urban expansion is predicted with commercial and residential development replacing horticultural forests along the southern islands of the atoll.

MAN HAS AFFECTED the distribution and abundance of plant species on the Pacific islands from the earliest contacts, but urbanization is a relatively recent and infrequent occurrence (Fosberg 1963). Although urban ecosystems are expanding units, descriptions and ecological investigations of their unique biological communities are rare (Schmid 1975). The current report describes the urban and nonurban vegetation of a Pacific atoll undergoing rapid change since 1944.

The extensive alteration and manipulation of plant communities by indigenous agriculturalists on Pacific atolls has been commented upon frequently (Bates and Abbott 1958, Niering 1963). On the atolls, the indigenous vascular flora is limited, with for example, 41 species on Kapingamarangi (Niering 1963) and 44 on Arno (Hatheway 1953). The arrival of ocean-going cultures began a process of plant introduction that significantly increased the vascular flora of most islands. For example, aboriginal introductions brought 16 species to Kapingamarangi (Niering 1963) and 24 species to Arno (Hatheway 1953). The atoll agriculturalists have removed or reduced the indigenous plant communities, replacing them with communities dominated by useful species. Only the driest atolls have escaped major vegetation changes (Fosberg 1956).

Trading and missionary influence began in the 1800s followed by military operations in the 1900s imposing further changes on the atoll ecosystems. In the early 1900s the commercial and administrative centers of European and Japanese interests became established on various islets of the atolls. With the onset of World War II, Japanese

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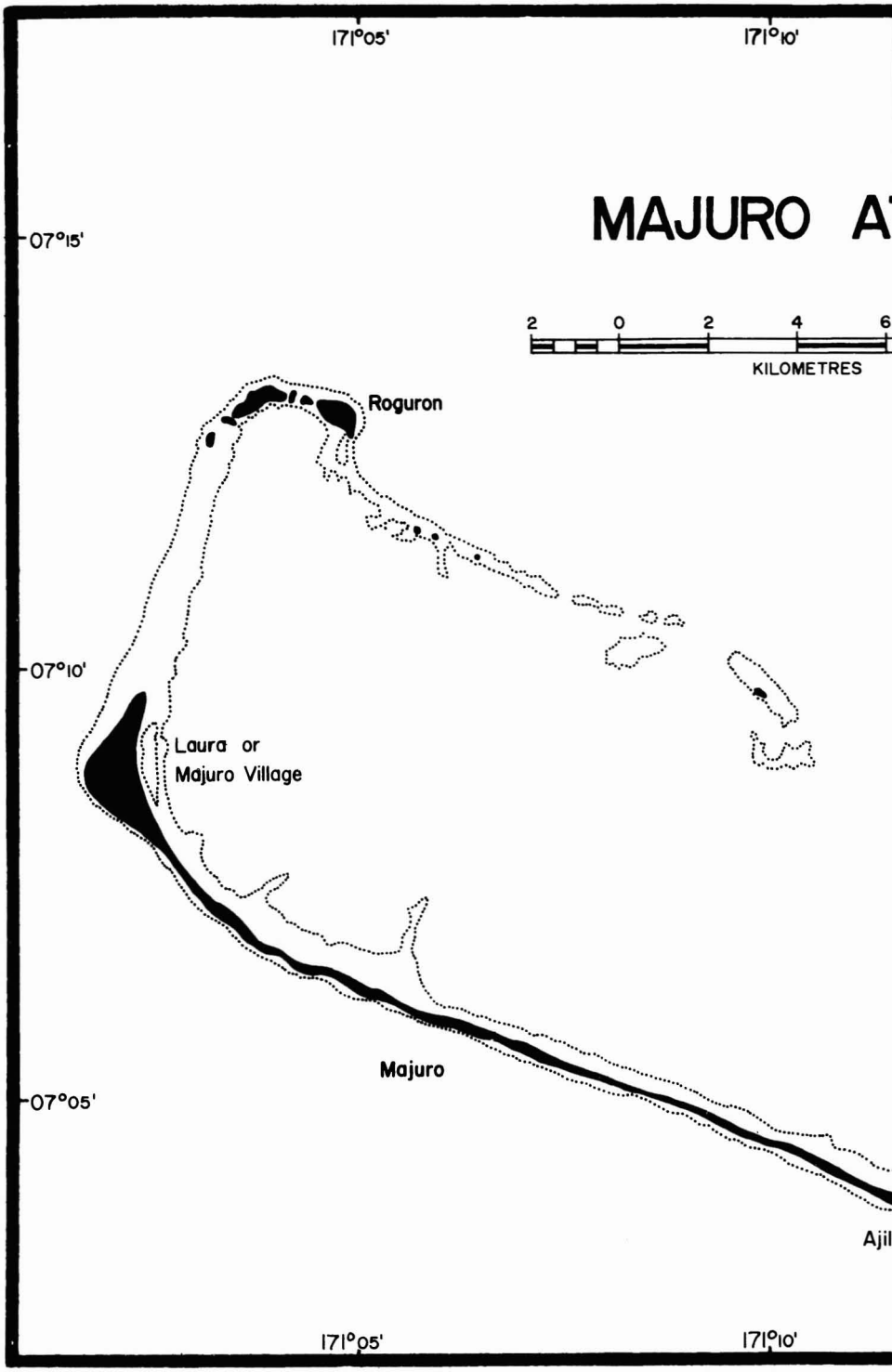
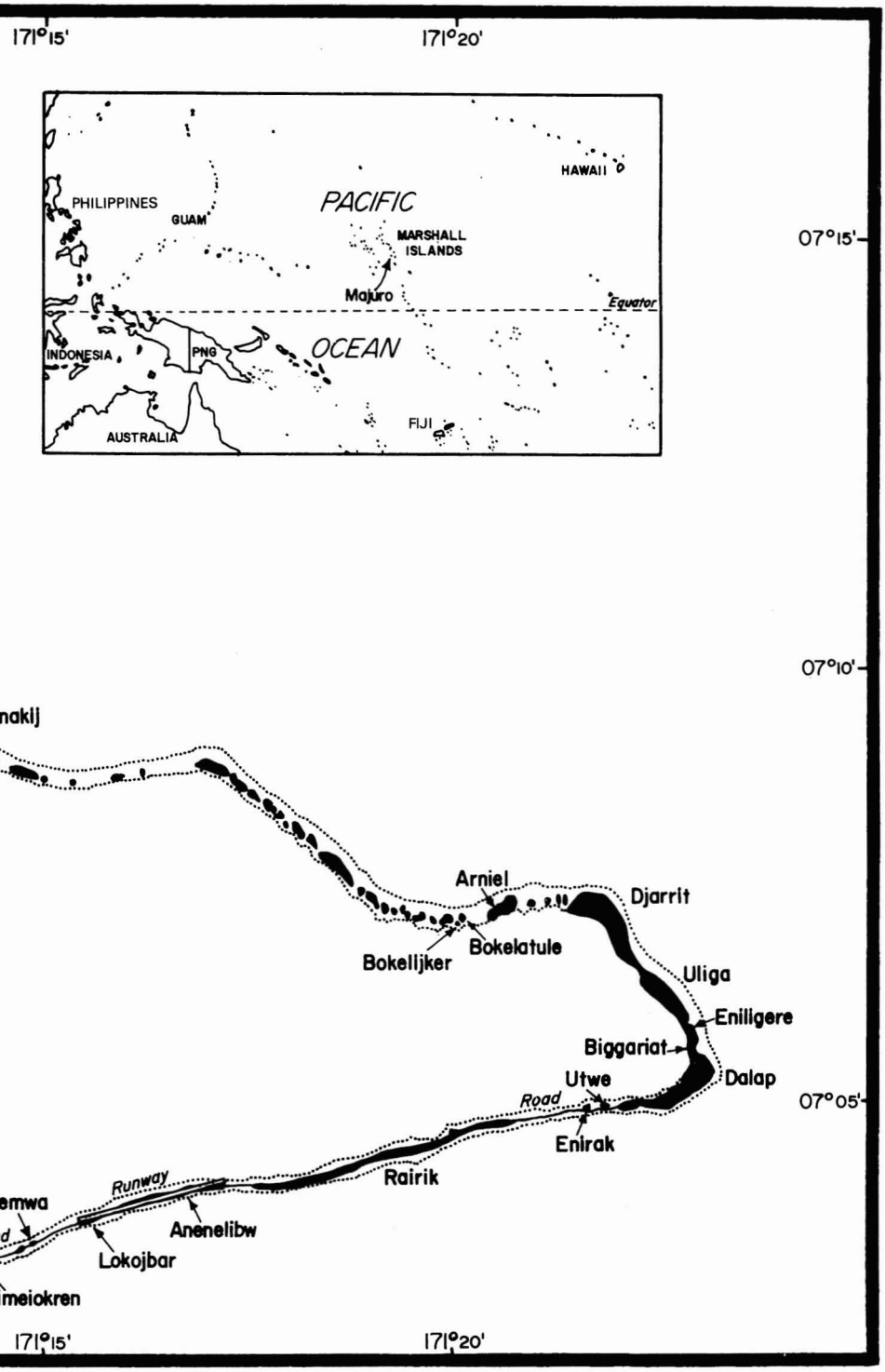


FIGURE 1. Map of Majuro Atoll, Marshall Islands.


171°15'
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PHILIPPINES
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nakij
Arniel
Djarrit
Bokelijker
Bokelatule
Uliga
Eniligere
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Road
Enirak
Runway
Rairik
emwa
Anenelibw
Lokojbar
imeiokren

and then United States military bases were established and abandoned. A few centers have continued in importance. Majuro and Kwajalein, Marshall Islands, have been developed for commercial, administrative, and military purposes, leading to population concentration and urbanization (Spoehr 1949).

METHODS AND MATERIALS

Majuro Atoll (7°07′ N, 171°12′ E) is located in the wet zone of the southern Ratak chain of the Marshall Islands. The atoll is about 297 km² in area, with 64 islands totaling 9.17 km² of dry land (Bryan 1971; see Figure 1 for map). Both temperature (annual average 27°C) and rainfall (annual average 308 cm) are relatively uniformly distributed throughout the year (Wiens 1962). Prior to 1944 the atoll economy was based upon subsistence horticulture and copra export (Spoehr 1949). Urbanization commenced in 1944 with the United States military occupation of Dalap, Uliga, and Djarrit in the eastern end of the atoll. At present, Majuro is being used for traditional horticulture, for copra production, and as an urban center.

The atoll was visited in 1974. Vegetational and cultural features were described quantitatively on the islets of Arniel, Uliga, Rairik, and Majuro. Qualitative descriptions were completed on Eniligere, Biggariat, Utwe, Enirak, Calalin, Allokan, Anemakij, Bokelijlker, Bokelatule, Lejemwa, and Limeiokren (place names according to Bryan 1971; see Figure 1). The locations for plant community analysis were determined by the availability of transport and aerial photography. Arniel was chosen as a relatively isolated island, without permanent occupants and reached only by boat. Rairik and the Ajiltake region of Majuro Island had permanent residents and were accessible by a main roadway, but contained forested areas still used for horticulture. Uliga was one of the three major urbanized islets with government, commercial, and residential development.

A vertical aerial photographic sequence taken in 1970 from Arniel along the eastern and southern island chain to Majuro Island at 1800 to 2500 ft altitude was used to construct detailed maps of vegetation and cultural features on Arniel, Rairik, Uliga, and Majuro. The locations and areas covered by buildings, roads, and cleared areas were determined from the photographs and major characteristics were verified on the ground.

A tree survey was completed on sections of Arniel, Uliga, Rairik, and Majuro by locating and identifying each tree in the 1970 aerial photographs on the ground. A tree was defined as any plant with greater than 10 cm diameter at breast height, or for *Pandanus tectorius* Soland and *Cocos nucifera* L., any specimen greater than 2 meters in height. Since the *Cocos* could be readily identified and located on the photographs without ground verification, only those individuals that had died since 1970 were recorded. From the photographs the following could be estimated: density of each species; foliage cover of major species; and individual location relative to cultural structures or saltwater.

In addition, aerial photography (oblique at 1000 feet altitude and vertical at an undetermined altitude) completed in January and December 1944, respectively, provided some evidence for change in vegetation patterns and cultural development over the 30 years since urbanization began.

In 1974, the shrub layer was analyzed on Uliga, Rairik, and Majuro to determine patterns of association with dwellings. A shrub was defined as any specimen less than 10 cm diameter at breast height, or for *Pandanus* and *Cocos*, any specimen less than 2 meters in height. On Rairik and Majuro four transects were laid out at right angles from each house site. Each transect consisted of a volume 70 meters in length, 1 meter in width, and 1 meter in height beginning 1 meter from ground level. All shrubs intersecting the transect volume were counted according to species and distance from the central dwelling. Only house sites that had been used for more than 10 years were included in the survey. A total of 25 house sites were sampled on both Majuro and Rairik. On Uliga the dwelling density prevented using this sampling technique on each

house. A crude shrub-layer description was derived from three cross-island transects.

RESULTS

Urbanization Since 1944

In the January 1944 oblique aerial photographs, Rairik appeared undisturbed by development and without indication of residences along the lagoon. By December 1944 the vertical aerial photographs reveal areas on Rairik being cleared of vegetation and an airplane runway established on the eastern end. The Rairik study area was undisturbed except for a small section that has since been planted in *Cocos*. The major *Artocarpus altilis* (Parkinson) Fosberg, groves were evident, but the photographic scale does not allow identification of individual trees. During 1944 the roadway that is still in use, connecting Rairik with Dalap, was constructed. Many house sites were evident in the same positions as presently occupied.

Photographs of Arniel in January 1944 showed the general pattern of *Artocarpus* and *Cocos* groves similar to that in 1974. However, the large *Calophyllum inophyllum* L. were not in evidence on the lagoon shore in 1944. House sites were in the same location in both years. The December 1944 photographs indicated no further development on Arniel.

Excellent oblique photographs taken in January 1944 exist for Djarrit, but Uliga and part of Dalap were photographed only at some distance. Djarrit was occupied by a small Japanese naval base beginning in 1940, but there were less than a few dozen buildings. Both Dalap and Djarrit were occupied by Marshallese prior to World War II, and at the beginning of 1944 there were small villages of about 400 people (Spoehr 1949). Uliga was not reported as being occupied in 1944 by either Japanese or Marshallese, and the photographs do not indicate any development. The island appeared to be covered with *Cocos* and possibly with some *Artocarpus*.

By December 1944 the vertical photographs confirm that the Djarrit–Uliga–Dalap area was occupied by a large United States military complex which established the major roads, runways, and building sites that existed in 1974. *Cocos* and *Artocarpus* had been extensively cleared, but on Uliga there seemed to be less activity.

Unfortunately photographs of the Ajiltake region of Majuro were not available, but few families lived in the area in 1947 (Spoehr 1949). The roadway connecting Majuro with the eastern islets was built in 1961 (Kabua and Pollock 1967) and undoubtedly contributed to further occupation of the Ajiltake region.

Based upon the 1944 photographs, the eastern and southern chain of islets were covered with a mixed *Cocos–Artocarpus* grove prior to development. From the history of development in the Marshall Islands (e.g., Arno) the extensive *Cocos* groves were probably established over much of the atoll in the late 1800s and early 1900s (Hatheway 1953). In 1944 all *Cocos* groves appeared mature, and are described currently by local informants as dating prior to World War II.

In 1945 the military demobilized rapidly, leaving only a small administrative unit by 1947. The Marshallese population began reoccupation of Djarrit and Dalap islands (Spoehr 1949). Subsequently, the Dalap–Uliga–Djarrit area became the administrative and commercial center for the atoll and for the Marshall Islands. The atoll population increased rapidly through migration and natality with the Djarrit–Dalap–Uliga area receiving the greatest increase (Table 1). Uliga, Eniligere, Biggariat, and Djarrit are currently urbanized with dense populations in mixed residential, commercial, and government land use.

Comparisons among Islands, 1974: Vegetation Cover

The relative proportion of forest canopy, open yards, roadways, and buildings as determined from the 1970 aerial photographs is presented in Table 2. Majuro, Rairik, and Arniel were forested islands with *Cocos* as a dominant. The *Cocos* canopy was occasionally broken by *Cordia subcordata* Lam., *Guettarda speciosa* L., *Artocarpus*, *Hernandia sonora* L., *Ficus tinctoria* Forst. f., and

TABLE 1

POPULATION HISTORY OF MAJURO

DATE	POPULATION			SOURCE
	Laura*	DUD†	Total	
1935	—	—	785	Bryan 1971
1948	—	—	1,236‡	Bryan 1971
1958	1,028	2,387	3,415	High Commissioners Office, Guam 1959
1970	—	—	7,165	Bryan 1971**
1970	1,572	5,829	7,301	U.S. Department of Commerce, Bureau of the Census 1971**
1973	2,287	8,003	10,290	Office of the High Commissioner, Saipan 1974

*Laura is the village on Majuro Island.
†DUD is the Djarrit–Uliga–Dalap region, now loosely referred to as Rita.
‡Spoehr (1949) reported that most of the 1947–1948 population was living on Majuro Island (Laura village).
**The differences in total population reported by Bryan and the Bureau of the Census in 1970 cannot be resolved, but the discrepancy does not alter the overall pattern of population change.

TABLE 2

PROPORTION OF VEGETATIONAL AND CULTURAL FEATURES IN THE STUDY AREAS ON MAJURO

CATEGORY	MAJURO	RAIRIK	ARNIEL	ULIGA
Housing	0.0012*	0.0038	0.0016	0.2057
Roads	0.0425	0.0422	0.0000	0.1759
Yards	0.0040	0.0000	0.0091	0.5587
Forest canopy	0.9523	0.9540	0.9893	0.0597

NOTE: Housing was considered to be buildings or residential dwellings. Roads were roadways actually in use and without vegetation. Yards were areas cleared of trees and shrubs, but with a ground layer of grasses, herbs, and sedges. Forest canopy was considered to be areas with tree cover over 2 meters in height.
*Proportion of coverage.

Calophyllum inophyllum L. Smaller individuals of these species, along with *Morinda citrifolia* L., *Pipturus argenteus* (Forst. f.) Wedd., *Premna obtusifolia* L., *Pandanus tectorius*, *Terminalia* sp., and young *Cocos nucifera* formed the understory. The *Artocarpus* groves contained *Cocos*, *Hernandia*, and *Cordia*, with understory species similar to the *Cocos* groves. Scattered *Artocarpus* groves occupied the interior sections of each island. The extent of *Artocarpus* groves was variable: on Rairik 26 percent of the total area; on Arniel 20 percent of the total area; and on Majuro 10 percent of the total area. A narrow band of indigenous species (*Guettarda speciosa*, *Scaevola taccada* L., *Tournefortia argentea* L.f., and *Pandanus tectorius*) usually only a few individuals in width occupied the ocean and lagoon shoreline. Arniel contained a small *Ochrosia oppositifolia* (Lam.) K. Schum. grove (23 individuals) on a boulder rampart facing the ocean. *Cocos* groves occupied the remaining areas of the three islands.

A single macadam road connected the administrative center in the Djarrit–Uliga–Dalap (Rita) area with the older village center (Laura) on Majuro Island. The roadway through the length of Rairik and Majuro islands formed a minor part of total land use. Arniel had a narrow path along the lagoon but was without roads. There were scattered houses on Arniel, Majuro, and Rairik that represented minor land use. Houses were constructed on a shallow coral rubble bed which was largely cleared of grasses, herbs, and most common understory shrubs for several meters from the dwellings. The small yards were planted with some ornamental and food-producing trees and shrubs. On Rairik the tree canopy enclosed the houses, reducing open yards to a minimum. The combined yards, houses, and roadways constituted less than 5 percent of the land area mapped on the three islands.

Urbanization had significantly reduced the forest canopy on Uliga (only 6 percent of total area), substituting a dominance of open yard (56 percent) with grasses, herbs, and

TABLE 3

DENSITIES OF TREE SPECIES ON MAJURO, RAIRIK, ARNIEL, AND ULIGA

SPECIES	MAJURO	RAIRIK	ARNIEL	ULIGA
Indigenous				
*Pandanus tectorius**	23.50	12.08	27.13	2.70
Guettarda speciosa	2.95	1.23	1.35	0.11
Scaevola taccada	1.73	0.65	0.41	0.23
Cordia subcordata	0.10	0.29	—	0.04
Tournefortia argentea	0.92	1.81	1.22	4.28
Pemphis acidula	0.20	1.39	—	—
Pipturus argenteus	0.71	—	—	—
Premna obtusifolia	—	0.16	—	—
Hernandia sonora	—	0.03	0.14	—
Bruguiera conjugata	—	0.13	—	—
Terminalia sp.	—	—	0.14	0.08
Ochrosia oppositifolia	—	—	3.11	0.04
Aboriginal				
Cocos nucifera	120.68	117.70	151.05	22.26
Artocarpus altilis	4.27	4.89	7.83	0.45
Calophyllum inophyllum	0.81	0.85	0.54	1.09
Ficus tinctorius	—	0.10	0.14	—
Morinda citrifolia	—	0.07	—	—
Recent				
Musa sp.	0.41	—	—	0.64
Carica papaya	0.20	0.16	—	0.60
Plumeria 2 sp.	—	—	—	1.58
Erythrina variegata	—	—	—	0.79
Hibiscus sp., ornamental	—	—	—	0.04
Casuarina sp.	—	—	—	0.19
Calotropis gigantea	—	—	—	0.11

NOTE: Origins are based upon Niering (1963), Hatheway (1953), and St. John (1951).
**Pandanus* should be included as either indigenous or aboriginally introduced, depending upon cultivar.

sedges surrounding houses (21 percent). Houses were associated with a shrub layer dominated by ornamental species. Roadways, paved or dirt, occupied 18 percent of the total area.

Comparisons among Islands, 1974: Tree Distribution

In Table 3 the tree densities (as individuals per hectare) on Majuro, Rairik, Arniel, and Uliga are grouped according to introduction history. *Pandanus* was represented by indigenous as well as introduced cultivars which are widely propagated for food. On Arno active propagation of *Bruguiera conjugata* (L.) Herr. led Hatheway (1953) to suggest that the species might not be indigenous.

With one exception, the density of indigenous species on Uliga was reduced in comparison with nonurbanized islands. The exception was *Tournefortia* which showed marked increase in density on Uliga. The increase might be explained as follows: *Tournefortia* occurred commonly on all islands as a shrub or small tree along lagoon or ocean shorelines. The clearing for yards on Uliga reduced the shoreline vegetation layer including *Tournefortia*, but most of the remaining individuals were tree size. Perhaps the selective clearing has reduced light and nutrient competition thereby increasing the density of tree-size *Tournefortia*.

The aboriginally introduced *Cocos* and *Artocarpus* were the most common canopy trees on Majuro, Rairik, and Arniel, but were significantly reduced on Uliga. *Ficus* was a rare tree in *Artocarpus* groves or in close association with houses. *Morinda* rarely attained sufficient size to be classified as a tree, but is widespread as an understory shrub in *Cocos* groves. Thus, the importance

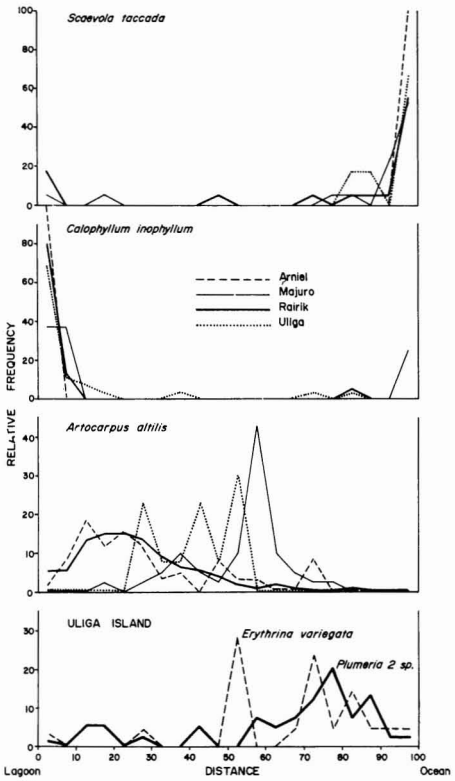

FIGURE 2. Relative frequency of tree species in relation to distance from lagoon or ocean.

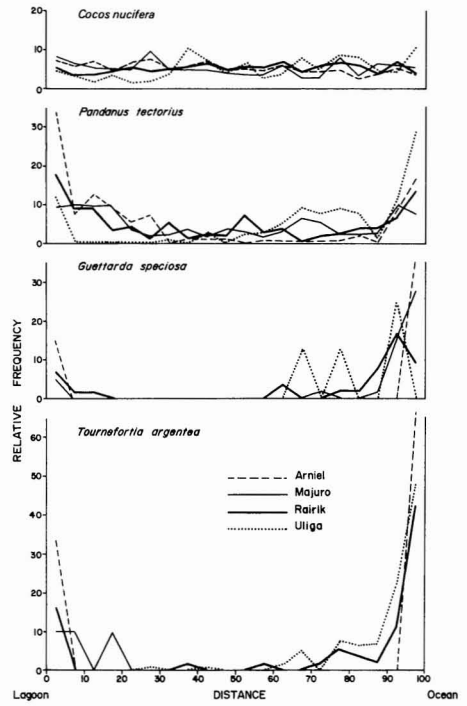

FIGURE 3. Relative frequency of tree species in relation to distance from lagoon or ocean.

attached to the presence or absence of tree-size *Morinda* or *Ficus* on any island is equivocal. *Calophyllum* was a common large tree along the lagoon shoreline. Houses were frequently built adjacent to large specimens that provided shade for work or play. The oblique aerial photographs of Arniel and Djarrit in 1944 did not show these easily recognized trees although they were common along the lagoon shoreline in 1974. The high density now seen on Uliga may be attributed to recent propagation.

The recently introduced tree species showed higher densities on Uliga than any other island area. *Plumeria* sp. and *Hibiscus* sp. were common in the immediate vicinity of houses on Rairik and Majuro but did not attain tree size. *Erythrina variegata* (L.) was observed occasionally in the secondary forest along the old World War II runways and military areas on eastern Rairik but did not occur in the study area. *Casuarina* sp. and *Calotropis gigantea* (L.) R. Br. were cultivated primarily in the urban areas. *Carica papaya* L. was frequently noted near houses on Majuro and Rairik but more frequently on Uliga. *Musa* sp. occurred only on Majuro and Uliga in close association with houses.

Groundwater, salinity, ocean spray, and cultivation practices are important determinants of plant distribution on a lagoon–ocean gradient (Hatheway 1953, Niering 1963, Fosberg 1956). The distributions of the seven most common tree species on a cross-island gradient is presented in Figures 2 and 3 for Majuro, Rairik, Arniel, and Uliga. The distance of an individual tree was measured from the lagoon and ocean shorelines, and then standardized to a scale of 0 to 100. The relative abundance of each species is plotted against the standardized scale.

The trees demonstrated three distinct patterns of distribution. First, a relatively uniform distribution was shown by *Cocos* on

all islands. On Uliga there was a slight decrease in *Cocos* frequencies between 10 and 35 on the scaled gradient, which was associated with a major roadway and building development.

Second, an increased abundance on the lagoon and/or ocean shoreline is shown by *Guettarda*, *Tournefortia*, *Pandanus*, *Scaevola*, and *Calophyllum*. *Pandanus* was distributed across all islands with increased abundance at both lagoon and ocean shores. *Scaevola*, *Tournefortia*, and *Guettarda* showed greater abundance along the ocean shoreline and were rarely found in the central areas. On the ocean side, these species along with *Pandanus* formed a tree–shrub layer that was left uncleared by the Marshallese and served as a barrier to salt spray (Hatheway 1953). *Calophyllum* was most common on the lagoon shoreline with an occasional specimen near the ocean or in the central area. On Uliga, where large-scale clearing had occurred, similar patterns of species distributions were clearly recognizable even though densities of most species were greatly reduced.

Third, *Artocarpus* was common in the center of all islands with an occasional individual near the lagoon on Arniel and Rairik. The distribution pattern on Uliga was similar to that on Rairik, Majuro, and Arniel but with reduced densities due to clearing and development. *Artocarpus* has a low tolerance for salt spray and saline groundwater, thus the species is restricted to propagation in the centers of larger islands (Fosberg 1949).

Figure 2 presents the distribution patterns for two recently introduced species found as trees only on Uliga, *Erythrina* and *Plumeria*. Both species increased in frequency in the island center since large specimens of both species were associated with residences and these tended to be located centrally.

Comparisons among Islands, 1974: Shrubs

Shrubs closely associated with houses on Rairik and Majuro are plotted in Figure 4. The ornamental *Stenolobium stans* L. and *Plumeria* sp. were clumped near houses. *Musa* and *Carica* rapidly declined in frequency with distance from the dwelling but were not as restricted in distribution. In addition to the species frequent enough to be plotted, occasional specimens of *Calotropis gigantea*, *Acalypha grandis* Benth., *Codiaeum variegatum* (L.) Bl., *Nerium oleander* L., *Hibiscus* sp., and *Citrus aurantifolia* (Christm.) Swingle were noted within 6 to 10 meters of house sites.

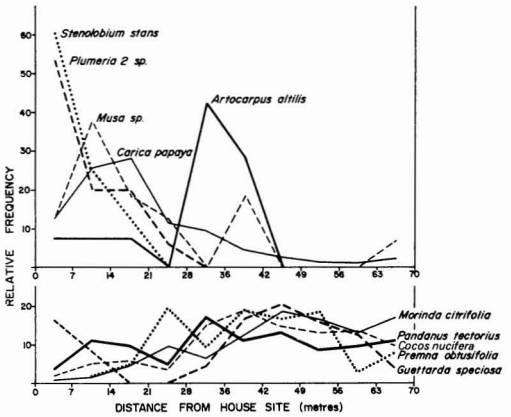

FIGURE 4. Relative frequency of ten common shrubs in relation to isolated houses.

Since the immediate house sites were usually kept clear of large trees and shade, *Artocarpus* would be expected to be cultivated at some distance from house sites. Indeed, young *Artocarpus* increased in abundance between 28 and 42 meters from dwelling sites but then declined. These distances may represent a Marshallese optimum distance for *Artocarpus* in relation to houses. However, the adult *Artocarpus* did not show a similar relationship with house sites.

Premna, *Pandanus*, *Morinda*, *Guettarda*, and sprouting *Cocos* formed the understory layer in *Cocos* groves. The understory layer was cleared from the immediate vicinity of houses, and the clearing activities are reflected in Figure 4. In order to facilitate copra collection, the shrub layer was slashed from the *Cocos* groves once or twice a year. During the clearing activities some specimens of *Morinda*, *Pandanus*, *Premna*, and *Guettarda* were left intact since each species is considered useful by the Marshallese. Occasional specimens of *Hernandia*, *Pipturus*, *Calo-*

phyllum, *Tournefortia*, and *Scaevola* were also encountered.

Although comparable shrub sampling on Uliga could not be completed, the cross-island transects revealed some differences. *Morinda*, *Premna*, and *Pipturus* usually associated with *Cocos* groves were absent from Uliga. *Crinum* sp., *Hibiscus*, and *Codiaeum* were used extensively on Uliga as ornamentals and occurred in markedly increased frequency. Young *Tournefortia*, *Scaevola*, *Pandanus*, and *Artocarpus* were present in limited numbers. Several ornamental species such as *Pseuderanthemum* sp., *Delonix regia* L., and *Cordyline* sp. were observed only on Uliga. In general, nonornamentals were reduced, but a few food species such as *Carica* and *Musa* were commonly cultivated.

Additions to Majuro Flora

Records of general floral collecting on Majuro Atoll are limited to a brief visit to Majuro Island resulting in 70 species (St. John 1951). Although limited in scope, the current study revealed seven taxa previously unrecorded: *Erythrina variegata*, *Casuarina* sp., *Delonix regia*, *Cordyline* sp., *Calotropis gigantea*, *Pluchea odorata* Nat. (L.) Cass., and *Nerium oleander*. Each species was closely associated with urban development and undoubtedly represented recent introductions.

DISCUSSION

Hatheway (1953) reconstructed the sequence of vegetation alteration for Arno, an atoll east of Majuro. Prior to human occupation, the islands were bordered with a shrub and tree layer of *Scaevola taccada*, *Tournefortia argentea*, *Pandanus tectorius*, *Terminalia samoensis* L., and *Guettarda speciosa*. Island interiors were forested with *Barringtonia asiatica*, *Hernandia sonora*, *Ochrosia oppositifolia*, *Intsia bijuga*, *Pandanus tectorius*, *Guettarda speciosa*, *Pisonia grandis* R. Brown, and *Cordia subcordata*. On sandy interior soils trees such as *Allophylus timorensis*, *Pipturus argenteus*, and *Premna obtusifolia* occurred. *Pemphis acidula* Forst. occupied the saline flats.

The early Marshallese established the horticultural subsistence agriculture that persists on many atolls. *Cocos nucifera*, *Artocarpus altilis*, *Morinda citrifolia*, *Calophyllum inophyllum*, and numerous cultivars of *Pandanus* were introduced to the interior forests. The areas covered by these aboriginally introduced species were relatively minor until the Marshallese came under the increasing influence of missionaries and traders. *Artocarpus* and *Cocos* groves were significantly expanded in the late 1800s. In response to the copra trade, *Cocos* were planted over large areas to become the dominant atoll tree. For example, in 1952, 69 percent of Arno Atoll was planted in *Cocos* (Hatheway 1953).

With the arrival of missionaries and traders in the late 1800s a new series of plant introductions began which brought *Erythrina*, *Carica*, *Citrus*, *Musa*, *Pemphis*, and *Plumeria*. Recent introductions have been dominated by ornamental trees and shrubs. On Arno, 20 of the total 48 trees and shrubs were recent introductions (Hatheway 1953), with 15 ornamental species. On Majuro, 11 of 14 recently introduced trees and shrubs were ornamentals.

Fosberg (1949, 1956) suggested that the wetter Marshallese atolls such as Majuro would have similar vegetation histories, species compositions, and associations. Spoehr (1949) describes a sequence of missionary, trader, and external governmental control for Majuro similar to that of Arno. Thus, Majuro was probably converted to *Cocos* plantations beginning in the late 1800s. By 1944 (based upon aerial photography), the *Cocos* groves were established in patterns similar to that seen in 1974 on Majuro, Rairik, Enirak, Utwe, and the islets from Calalin to Djarrit.

In 1974, the indigenous species were extremely limited in distribution and relative abundance on the *Cocos*- and *Artocarpus*-dominated islets. Lagoon and ocean shoreline species (*Tournefortia*, *Scaevola*, *Pandanus*, and *Guettarda*) seemed most successful since they were retained by Marshallese for salt-spray protection. These species persisted even on the urbanized islets. The cultivation of *Cocos* and *Artocarpus* has largely eliminated

TABLE 4

POPULATION DENSITIES ON ARNO AND MAJURO, 1935–1970

YEAR	MAJURO (Individuals/km²)	ARNO (Individuals/km²)
1935	85.6	73.1
1948	134.8	85.5
1970	798.2	53.8

SOURCE: Based upon Bryan (1971).

indigenous forest associations. *Ochrosia* was limited to the small groves on Arniel and Anemakij. *Pisonia* was observed only as a small grove (21 individuals) of understory saplings on Anemakij. *Barringtonia asiatica* was absent as a tree, but was being cultivated by the Agriculture Department for ornamental plantings.

Regeneration of indigenous forest was possibly occurring on eastern Rairik island on abandoned military areas. Secondary growth contained indigenous *Terminalia*, *Hibiscus tiliaceus*, *Tournefortia*, *Guettarda*, and *Scaevola*, but also introduced species such as *Erythrina* and *Cocos*. Although the northwestern islands near Roguron were not observed, it seems unlikely that Majuro has any significant areas of indigenous forest. For comparison, Arno had 18 percent of the total area covered by some indigenous forest type (Hatheway 1953). The greater extent of *Cocos* and *Artocarpus* on Majuro may reflect the greater population density evident since 1935 (see Table 4), placing greater demands upon the horticultural subsistence agriculture and copra production.

The plant communities on nonurbanized islands of Majuro Atoll closely resembled those described for other Pacific atolls (Fosberg 1949, 1956). Although quantitative description is available for Arno (Hatheway 1953) and the East Carolinian atoll of Kapingamarangi (Niering 1963), direct comparison with Majuro is not easily accomplished. Both descriptions rely on data determined from "pure" stands of *Artocarpus* or *Cocos*. The difficulties of a typological approach to plant communities are well known (Kershaw 1973). The current study was completed on islands with mixed vegetation, thus precluding direct comparison with Arno or Kapingamarangi.

Over the last 30 years, urbanization has altered indigenous and aboriginally introduced plant communities primarily by replacing forested areas with open yards. The urban vegetation is characterized by scattered trees resulting in open canopy; a high percentage of ornamental shrubs; and dominance of yards containing grasses, herbs, and sedges. Most of the ornamental trees and shrubs had been recorded in Laura village on Majuro Island prior to major development (St. John 1951). The recently introduced species could be found around the isolated family dwellings in the *Cocos* and *Artocarpus* groves on Rairik and Majuro. Indeed, the urban shrub and tree communities appeared to be an extension of patterns set in these isolated dwellings. If rural dwellings with their closely associated plants were placed together at an urban density, then the existing urban vegetation patterns could easily be derived.

Although the urban areas contained a high percentage of ornamentals, indigenous and aboriginally introduced species were also common. For example, the trees were dominated by *Cocos* and *Tournefortia*. *Calophyllum* and *Pandanus* were common shade trees. A number of new plantings of *Guettarda*, *Scaevola*, and *Tournefortia* were evident, but understory species such as *Morinda*, *Pipturus*, and *Premna* were absent.

The establishment in 1944 of a major military center on Majuro followed by governmental and commercial activities stimulated urbanization resulting in rapid population growth (see Table 1). The future expansion of urbanized areas seems assured. Since 1970 a new airfield to accommodate major jet air traffic has been built over Anenelibw and Lokojbar islets (see Figure 1). The mile-long runway with adjacent roadway and passenger-freight processing areas established another major urban vegetation center. In 1974, *Tournefortia*, *Scaevola*, and *Cocos* were beginning to reinvade the construction areas, and ornamental plantings were commencing. The airport location, approximately midway between the Djarrit–Uliga–Dalap area and Majuro islet, seems

likely to stimulate further development on both Rairik and the eastern end of Majuro islet. New residential construction was proceeding on Rairik with several Gilbertese families recently occupying new house sites. Speculation among Marshallese regarding continued tourist development on both Rairik and Majuro was evident.

The population increase with subsequent urban development has resulted from a shift in economic base from subsistence horticulture to an import–export monetary economy. Although the final dimensions of the urbanization cannot be predicted at present, certainly the expanding emphasis on Majuro as a governmental and commercial center will probably widen urban development to include all of Rairik and the Ajiltake region of Majuro islet. Some residential and commercial construction was continuing on Dalap in small sections of uncleared land. The lack of roadways along the northern island chain beyond Dalap seems, for the present, to be a barrier to urban development.

Unfortunately, comparison with other Pacific urban areas is not possible since detailed descriptions are unavailable. While considerable information has been obtained on the floristics of many islands, few data are available on the structure of the plant communities. Based upon observations on Majuro it would appear that a distinct, new man-controlled plant community has become established in the Pacific islands. The components represent indigenous, as well as aboriginally and recently introduced species. Some species are successfully sexually reproducing while others are simply clones. The dynamic interaction of climate, soils, the component species, and man to form the new community remain largely unexplored.

ACKNOWLEDGMENTS

The following people have aided the project by offering information or advice: B. Melde, D. Abel, E. H. Bryan, J. S. Ravina, D. Anderson, P. Van Royen, B. Bender, and C. Lamoureux. Liki Labi extended aid and the support of the Agriculture Department on Majuro. The project could not have been completed without the extensive field assistance provided by Ritten Nathan. The Marsh Fund of the National Academy of Sciences (U.S.) and the Society of Sigma Xi supplied financial aid for field expenses. Aubrey Chandica of Griffith University introduced me to some finer points of interpreting aerial photography, completed maps and illustrations for analysis, and provided the figures in the text. Ruth Forrest and Janine Smith provided excellent typing assistance.

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