

**Vegetation Classification Support for
War in the Pacific National Historical Park (WAPA)
on Guam, and American Memorial Park (AMME) on
the Northern Mariana Islands**

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PART 1. WAR IN THE PACIFIC NATIONAL HISTORICAL PARK

INTRODUCTION

Guam is an unincorporated territory of the U.S., located between 13.2° N and 13.7° N and between 144.6°E and 145.0°E, and has an area of 209 mi². (541 km²). The island is 30 miles (48 km) long and 4 to 12 miles (6 to 19 km) wide. It is the southernmost island in the Marianas chain and is the largest island in Micronesia. The highest point on the island is Mount Lamlam, which is 1332 ft (406 m) in elevation. Unlike the Anatahan volcano in the Northern Mariana Islands, Guam is not volcanically active. The northern part of the island is a forested coralline limestone plateau while the southern contains ancient volcanic peaks covered in forest and grassland. A coral reef surrounds most of the island, except in areas where bays exist that provide access to small rivers and streams that run down from the hills into the Pacific Ocean and Philippine Sea. The population of Guam, as of 2007, is estimated to be 173,460.

The War in the the Pacific National Historical Park (WAPA) comprises seven management units (Fig. 1): Asan Beach, Asan Inland, Fonte Plateau, Piti guns, Agat, Mt. Chachao-Mount Tenjo, and Mt. Alifan. The total area of these units is 1928 acres (780 ha), of which 926 acres (375 ha) comprise terrestrial areas and vegetation. The remainder of the WAPA comprises marine systems (Anon. 2005). The units are further described as follows:

The Asan Beach Unit, located along the ocean side of Marine Corps Drive between Asan Point and Adelup Point, comprises 109 acres (44 ha) of land area. Most of the land area is found in the Asan Memorial Beach.

The Asan Inland Unit comprises 593 acres (240 ha) between Asan Village near sea level and Nimitz Hill at about 500 ft (150 m) in elevation. It is the largest of the units, and consists primarily of disturbed, alien-dominated savanna that is still periodically devastated by human-set fires.

The Piti Guns Unit comprises 98 acres (40 ha) above the village of Piti and encompasses much of the upper reaches of Taguag River to the east, from about 40 to 340 ft (12–104 m) in elevation. This unit features three cannons that the Japanese planned to use during World War II, but which were never fired. They are a popular tourist attraction.

The Fonte Plateau Unit is located along Route 8 between 460 and 640 ft (140–195 m) in elevation. Its 38 acre (15 ha) size makes it one of the smallest of the units. It is primarily a scarcely vegetated stone quarry that contains a cave that was once the site of the Japanese Command Post in World War II.

The Mt. Chachao-Mt. Tenjo Unit is located along a narrow strip of land on the ridge between Mt. Chachao and Mt. Tenjo. It ranges from an elevation of 880 ft (268 m) at its lowest point to 1042 ft (318 m) at the top of Mt. Chachao. This 45 acre (18 ha) strip of land is included in the WAPA because it was used as a vantage point by Japanese forces during World War II.

The Agat Unit comprises three non-contiguous terrestrial subunits comprising 37 acres (15 ha) located over 1.2 miles (2 km) of shoreline in Agat. It is the smallest of the WAPA units. The Apaca Point subunit is located just north of the mouth of the Namo River at near sea level. It includes the small Pelagi Islets just offshore. The Gaan Point subunit comprises a large lawn area at the mouth of the Salinas River at near sea level. The Bangi Point subunit is located on the shore adjacent to Inaso Maso Village, and includes the small offshore islets of Alutom, Yona, and Bangi.

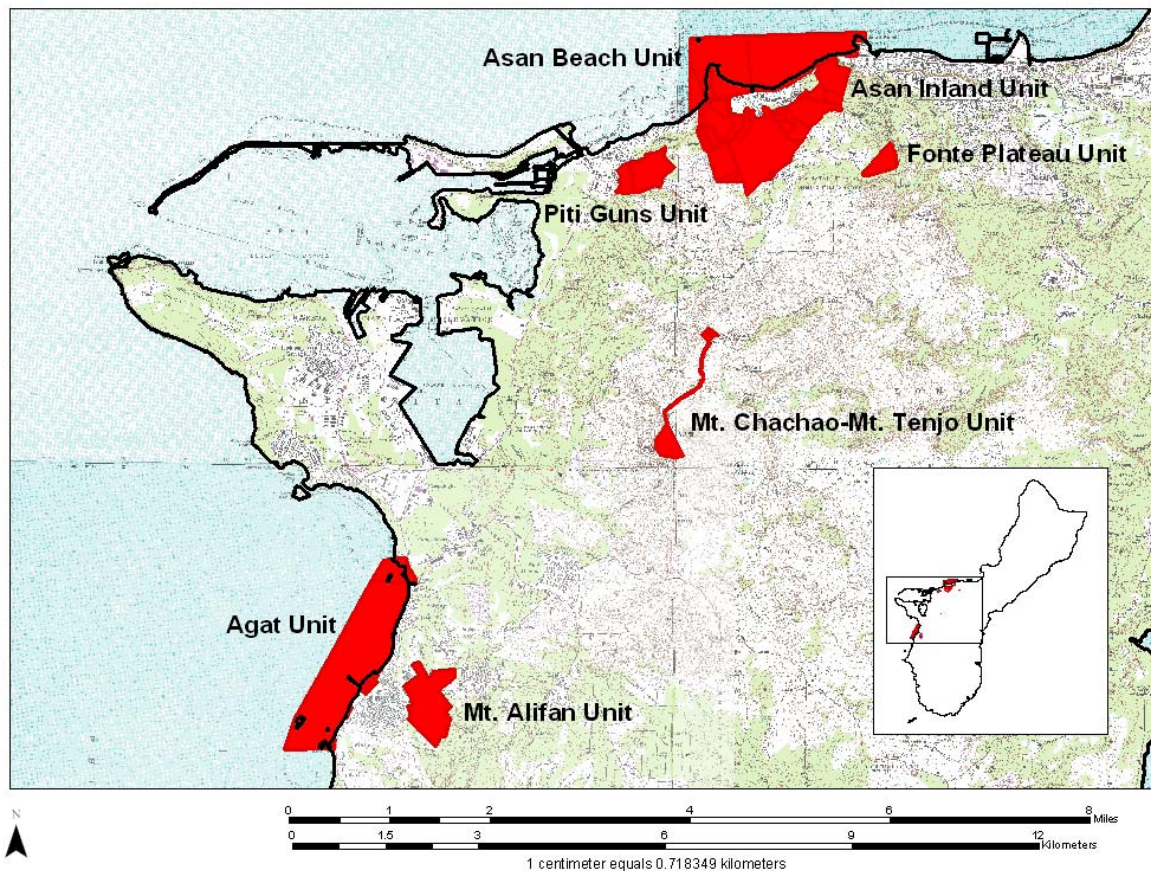


Fig. 1. Map of the units of the War in the Pacific National Historical Park.

The Mt. Alifan unit is located above the village of Agat and adjacent to and west of Santa Rita. Its 158 acres (64 ha) area lies on the western slopes of Mt. Alifan (870 ft, 265 m), ranging from 30 to 600 ft (10–180 m) in elevation. It is an historical battlefield from World War II.

A management plan for the park was prepared during the early stages (Anon. 1983).

GEOLOGY

The island of Guam consists essentially of volcanic rock and coral limestone, enclosed by a fringing reef of coral. It is the southernmost and largest mountain of the submerged volcanic range which extends southward from central Japan, through the Volcano Islands and Bonins to the Marianas. Guam is a large volcanic base which has been repeatedly elevated, on which coral limestone has repeatedly formed. The northern portion of Guam is a plateau—flat but not horizontal, gradually sloping from somewhat over 500 ft (150 m) above the sea on the east to 200–400 (60–120 m) on the west, with steep cliffs on all sides toward the ocean, only occasionally broken by slopes or gaps or even readily negotiable trails, with small beaches of fine sand around the bays and coves between the high projecting points. The limestone plateau of the north, formerly densely forested but now virtually cleared of large trees, is without

running water. The narrow waist of the island, from Pago Bay to Agana Bay, consists largely of swamp and small river valleys, and rather densely-grown or intensely cultivated low hills. The southern half is mountainous and surprisingly rugged, draining largely eastward into the Fena or Talafofo River, dropping to the sea in steep ridges and foothills and little valleys at numerous small bays, instead of high cliffs. Much of the south is covered by grassland.

The entire northern half is a shelving, more or less flat, plateau of metamorphosed coral limestone, a terrace atop a submerged volcanic base. The limestone plateau is interrupted only by Mt. Santa Rosa rising to elevation 870 ft (265 m) from 600 ft (183 m) elevation at its base, with the surrounding plateau at between 500–600 ft (152–183 m) elevation. It is a comparatively recent small volcanic hill—not an actual crater itself, but composed of volcanic rock. A second hill further south is of limestone, a bulge or a remnant—Barrigada, 674 ft (205 m) elevation, rising from a surrounding 400-ft (122 m) level. The 200–500 ft (61–152 m) cliffs bounding the plateau are very abrupt, nearly vertical, with only occasional breaks. Stone (1970) noted in his flora of Guam that the island was 1000–1500 ft (305–453 m) higher than it is today.

CLIMATE

The climate of Guam is definitely tropical and is pleasantly warm the year-round. The mean annual temperature is 80° F (27° C). Generally, it ranges from the low 70s at night to the middle of the 80s during the day. The coolest and least humid months, marked by prevailing westerly trade winds, are in December through February. Although the warmest months are from March through August, the refreshing trade winds blow steadily. The annual rainfall totals 80 to 110 inches (2000 to 2750 mm). There are two seasons, the dry and the rainy. The dry season runs from December through June, and the rainy season falls within the remaining months. The first six months of the year average about 4 inches (100 mm) a month, the last six months about 10 (250 mm). During the dry season, fires are a recurring problem on the savannas, and shape their vegetation. This fire regimen favors species that are adapted to survival during fire.

The other major climatic factor affecting the vegetation are the periodic hurricanes (called typhoons in that part of the world). An average of 31 tropical storms develop in the western north Pacific every year with typically one or more affecting Guam. Over 16 typhoons have hit Guam since 1970 and the island has been devastated by four since 1960. The strong winds wreak havoc on the vegetation, creating forests dominated by relatively short trees that are best suited to withstand the effects of the storm.

FLORA

Collection of the flora of Guam began in 1792 during the Spanish colonial era. A number of collections, mostly by visiting expeditions, were gathered and sent back to Europe, but little was done on them as a group. At the beginning of the American era in Guam (1898), the first publication on the plants as a whole was prepared by Safford (1905). The first work specifically on the flora of Guam was done by E.D. Merrill (1914). Merrill and Perry (1948) also provided a listing of the flora, and in the same year, a summary of the flora by S. Glassman (1948) was published. After that, numerous collections were made in Guam by F.R. Fosberg, who was the most significant and prolific collector in Micronesia from the 1950s through the 1980s.

The most up-to-date work on the flora of Guam can be extracted from the publications of Fosberg et al. (1979, 1982, and 1987), which includes all of Micronesia, and from *The Flora of*

Guam published by B.C. Stone (1970), which is specific to Guam. There have been only minor publications on the plants since then, including one on orchids of the Marianas (Raulerson and Rinehart 1992), which includes Guam. The flora is currently under study by L. Raulerson at the University of Guam. In his book, Stone estimates the native vascular plant flora comprises 346 species. This includes 56 ferns, one gymnosperm (a cycad), and 270 Angiosperms.

A study of the flora and vegetation of the WAPA was done by Yoshioka (2008), who recorded of 392 plant species. The total represents two fern allies, 38 ferns, one gymnosperm, 228 dicots, and 123 monocots. Of the 392 vascular plant species recorded from the WAPA, 173 (44%) are native, 210 (54%) are alien, and nine (2%) are unidentified. Of those that are native, 15 (4% of all taxa) are endemic, which means that they are unique to the Mariana Islands.

VEGETATION

Information on the vegetation of Guam can be found in a number of sources. Descriptions of the vegetation date back to early explorers to the region. Gaudichaud (1826) left a valuable account that shows a considerable degree of understanding and helps to explain present conditions. Stone, in his *Flora of Guam* (1970), noted five major types of substrate for plant life: laterite (from ancient ash and lava), riverine mud (chiefly derived from laterites), coral rock (and its derivative clay soils), coral sand (derived from coral rock by wave action), and mixtures of coral and laterite soils (“argillaceous soils”). He also provided a map of these units on Guam, and noted that the majority of the endemic plant species of Guam occur on the coralline soils. Further work was done on the soils of Guam by Young (1988).

The major work on the vegetation of Guam was published by F.R. Fosberg (1960) in his *Vegetation of Micronesia*, the Guam portion of which was summarized by Stone. Fosberg divided the vegetation into nine types, as follows:

Type 1—Forests of elevated hard limestones. This category is also called “typhoon forest,” because of its adaptations to the frequent and periodic typhoons that lash the island. It occurs mostly on the northern half of the island, but also in scattered localities in the southern half. He recognized seven subtypes of this:

Subtype a, called mixed moist forest, dominated by *Artocarpus mariannensis* (Marianas breadfruit) and *Ficus prolixa* (a banyan), along with many other tree species.

Subtype b, with is similar to subtype “a” but which virtually or entirely lacks the breadfruit.

Subtype c, *Mammea* forest, dominated by *Mammea odorata*, and found mostly on cliffs and terraces near the sea. It is sometimes mixed with the fish-poison tree *Barringtonia asiatica*.

Subtype d, *Cordia* forest, dominated by *Cordia subcordata*. Only one locality of this was Mentioned on Guam, behind Tarague Beach.

Subtype e, *Merrilliodendron* forest, characterized by *Merrilliodendron megacarpum*, which

is locally abundant. He noted this as occurring on the Haputo limestone terraces.

Subtype f, *Pandanus* forest, dominated by screwpines (*Pandanus* spp.). It may be temporary

and eventually replaced by other types.

Subtype g, halophytic-xerophytic scrub, a scrubby littoral type of vegetation occurring on

limestone rocks and cliffs receiving ocean spray or winds directly off the ocean. It is typically dominated by shrubs, such as *Scaevola taccada* and *Pemphis acidula*.

Type 2—Ravine forest. This occurs mainly on volcanic, argillaceous, or limestone soil on the southern part of Guam. The tree stature is low, and characteristic species include *Hibiscus tiliaceus* (beach hibiscus), *Pandanus tectorius* (screwpine), and *Ficus prolixa* (a banyan).

Type 3—Marshes. Seven subtypes of herbaceous wetland vegetation were recognized on Guam.

Subtype a, reed marsh, dominated by *Phragmites australis*.

Subtype b, bulrush marsh, dominated by *Scirpus littoralis*, and chiefly found around Apra Harbor.

Subtype c, *Cyperus* marsh, dominated by *Pycnus polystachyos* or *Torulinum odoratum*. (Both species were formerly classified in the genus *Cyperus*.)

Subtype d, *Paspalum* marsh, dominated by the grass *Paspalum vaginatum*. This is typically found in areas of brackish water near the coast.

Subtype e, *Brachiaria* marsh, dominated by the invasive California grass *Brachiaria mutica*.

Subtype f, rice and taro patches, dominated by the two cultivated food plants.

Subtype g, *Acrostichum* marsh, dominated by the mangrove fern *Acrostichum aureum*.

Type 4—Swamps. Two major types of wetland forest are included here, freshwater swamps and mangroves. Three subtypes are recognized:

Subtype a, true mangrove formation, found mostly around Apra Harbor and dominated by *Rhizophora* spp. (red mangroves), *Bruguiera gymnorhiza* (oriental mangrove), *Lumnitzera littorea*, and several other mangrove species.

Subtype b, pure *Nipa* strands, dominated by the wetland palm *Nipa fruitcans*.

Subtype c, riverine *Barringtonia* swamp, dominated by *Barringtonia racemosa*, and known only along the Talafofo River.

Type 5—Strand vegetation. This is the herbaceous vegetation that covers many of Guam's beaches, and is dominated by grasses, such as *Lepturus repens* and *Thuarea involuta*; vines, such as *Ipomoea pes-caprae* (beach morning-glory) and *Vigna marina* (beach pea); shrubs, such as *Scaevola taccada* (scaevola) and *Wollastonia biflora* (beach sunflower); and trees, such as *Casuarina equisetifolia* (ironwood) and coconuts. Elsewhere in the Pacific, this type of vegetation is typically broken up into zones based on life form (e.g., herbaceous strand or "pes-caprae formation," littoral shrubland, and littoral forest).

Type 6—Savannas. This occurs on volcanic soils, mostly on the southern part of the island. It is divided into four subtypes:

Subtype a, *Miscanthus* community, dominated by *Miscanthus floridulus* (swordgrass).

Subtype b, *Dimeria chloridiformis* community, dominated by the eponymous grass.

Subtype c, erosion scar community, dominated by pioneer species, such as *Dicranopteris linearis* (false staghorn fern), *Casuarina equisetifolia* (ironwood), *Myrtella bennigseniana*, and many other shrubby species.

Subtype d, *Phragmites karka* valleys, dominated by the reed *Phragmites australis* (formerly called *P. karka*). This one is botanically very similar to the marsh subtype

“a,” since it is dominated by the same reed.

Type 7—Argillaceous Limestone Vegetation. This type of scrub forest is almost entirely dominated by alien shrub and scrubby tree species, particularly by *Leucaena leucocephala* (tangantangan). It is characteristic of the central part of the island.

Type 8—Coconut groves. This comprises coconut plantations, as the name implies.

Type 9—Weed communities. This comprises all vegetation types dominated by weedy herbaceous vegetation.

A vegetation map of Guam, produced by Fosberg, was published in Stone (1970). Moore and McMakin (1979) also produced a well-illustrated guide book summarizing the vegetation types of Guam. Six types were recognized there: limestone forest, savanna, swamps, marshes, strand, and farm.

A more comprehensive vegetation scheme, of all of the Pacific Islands, was published by Mueller-Dombois and Fosberg (1998). It included a general description of the vegetation types in Micronesia, and a more specific discussion of each of the islands. They noted that most of Guam is forested, but that large areas are covered by coarse grasses. “Most of the island is covered by a mosaic of small patches of extremely varied appearance. The forests are mostly second growth, many of them irregular thickets, generally dense, tangled, and often with spiny undergrowth.” They divided the vegetation of Guam into two categories, Northern Limestone Vegetation and Southern Volcanic Soil Vegetation. The Northern Limestone Vegetation was divided into five categories: *Artocarpus-Ficus* forest, *Mammea* forest, *Cordia* forest, *Merrillioidendron-Ficus* forest, and *Pandanus* forest. These are nearly the same as the “Type 1—Forests of elevated hard limestones,” subtypes a, c, d, e, and f that were earlier recognized by Fosberg (1960), except that the *Ficus* (*F. prolixa*) was added to subtype e to make the *Merrillioidendron-Ficus* forest category. They also noted the presence of patches of tall grasses, thickets, and large areas of *Leucaena* forest-scrub and coconut groves. They also made brief mention of marshes, one inland and the others coastal, in the area.

They described the vegetation of the Southern Volcanic Soil Vegetation category as being a complex mosaic of grassland and forest. The grasslands are believed to be mostly the result of repeated burnings over the centuries. This typically results in grasslands dominated by swordgrass (*Miscanthus floridulus*), especially on slopes (Minton 2005). Other grasses dominate in different topography. If left unburned for many years, they are often invaded by *Casuarina equisetifolia* (ironwood), but when fires erupt, these trees are usually killed. On their vegetation map, Mueller-Dombois and Fosberg (1998) recognized nine categories that more or less correspond to those in Fosberg (1960) and Stone (1970).

1. Forest on Elevated Limestone Plateaus and Cliffs. This corresponds to Fosberg’s “Type 1—Forests of elevated hard limestones.”

2. Savanna Complex. This corresponds to Fosberg’s “Type 6—Savannas,” with four subtypes (which are not recognized in their publication).

3. Swamp Forest Complex, including Mangroves. This corresponds to Fosberg’s “Type 4—Swamps,” and its three subtypes.

4. Ravine Forest on Volcanic Soil and on Limestone Outcrops in Valleys. This corresponds to Fosberg’s “Type 2—Ravine Forest.”

5. Secondary Thickets and Partially Cultivated Scrub Forest. This corresponds to Fosberg's extremely disturbed "Type 7—Argillaceous Limestone Vegetation."

6. Coconut Plantation. This corresponds to Fosberg's "Type 8—Coconut groves."

7. Predominantly Open Ground and Pastures. This corresponds to Fosberg's "Type 9—Weed Communities."

8. Urban Vegetation around Military Installations and Cities. This is probably best considered to belong to the Type 9 Weed Communities. The two are often lumped together elsewhere in the Pacific as "Managed Land Vegetation."

9. Reed Marsh with mostly *Phragmites australis* (as *P. karka*). This corresponds to Fosberg's "Type 3—Marshes, Subtype a, reed marsh," dominated by *Phragmites australis* (the commonly accepted name for the species now).

This system leaves out the six types of marshes in Type 3, and Type 5, Strand Vegetation. The latter is probably excluded from the map since it usually comprises a very narrow zone of vegetation is too narrow to show up on it. Additional work was done on the forests of Guam by Donnagan et al. (2002).

The standard way to categorize vegetation is to first divide it into plant communities, then to further divide it into associations. A plant community is a unit of similar vegetation distinguished from other plant communities by its structure and habitat. The mangrove community, for example, is a forest occurring in saline conditions on the coast, so it is defined by both structure (forest) and habitat (saline conditions). Many of the plant communities are further divided into "associations" based upon their flora—usually upon their dominant plant or plants. The marshes in Guam, for example, were divided by Fosberg (1960) into several subtypes (associations) based upon which species are dominant. Different authors studying different areas of the Pacific or the world use different schemes to distinguish the vegetation patterns, so the plant communities and associations recognized here are not identical to those recognized by other authors working in Guam, in other areas of the Pacific, or elsewhere in the tropics, but debating the merits of the different systems is beyond the scope of this report.

VEGETATION OF THE PARK

The only description of the vegetation of the War in the Pacific National Historical Park is found in Yoshioka (2008). She recognized the following vegetation types in the seven units of the WAPA:

Asan Beach Unit

- Beach Strand

- Disturbed Limestone Forest

- Maintained Lawn

Asan Inland Unit

- Savanna Complex

- Mixed Limestone Forest

- Mixed Ravine Forest

- Riverine Community

Fonte Plateau Unit

- Non-Operational Quarry

- Limestone Forest

- Mixed Forest in Volcanic Soil on Limestone
- Piti Guns Unit
 - Mahogany (*Swietenia macrophylla*) forest
 - Savanna Complex
 - Riparian Community
- Mt. Chachao-Mt. Tenjo Unit
 - Savanna
 - Ravine Forest
- Agat Unit
 - lawn, parking area, and near-shore beach strand areas
- Mt. Alifan Unit
 - Limestone Forest
 - Riverine Community
 - Savanna

Summarizing the previous publications, especially Yoshioka who was the only person to study the vegetation of the WAPA, the following types of vegetation are recognized and discussed here:

- Littoral Strand Community
- Limestone Forest Community
- Ravine Forest Community
- Phragmites* Marsh Association
- Savanna Community
- Mahogany Forest Association
- Managed Land Vegetation (Lawns)

Littoral Strand Community

The Littoral Strand community comprises the vegetation found on the immediate shores of Guam. In the WAPA, it occurs only at the Asan Beach and the Agat Unit (including all three subunits). It is very poorly developed on the latter, and Yoshioka (2008) did not even assign the beach vegetation there to a vegetation unit. The beach vegetation in the WAPA can be considered part of the Littoral Strand community, a term not used by any of the major publications on the vegetation of Guam. Fosberg (1970) referred to it as Strand Vegetation, noting that it was the herbaceous vegetation covering many of Guam's beaches, and dominated by grasses, such as *Lepturus repens* and *Thuarea involuta*; vines, such as *Ipomoea pes-caprae* (beach morning-glory) and *Vigna marina* (beach pea); shrubs, such as *Scaevola taccada* (scaevola) and *Wollastonia biflora* (beach sunflower); and trees, such as *Casuarina equisetifolia* (ironwood) and coconuts. This vegetation was not noted on the map of the vegetation of Guam by Mueller-Dombois and Fosberg (1998), probably because it forms such a narrow zone that it would not show up on the scale of the map they were using. Yoshioka (2008) used the term "Beach Strand," in the WAPA, but only at Asan. She noted similar but unnamed vegetation at the Agat Beach Unit.

Littoral Strand is often not homogeneous since several zones, differing in life form and flora, can sometimes be distinguished. Some authors classify these zones into plant communities

because of the difference in physical structure and flora, but because of their narrow extent, their commonalities, and the indistinct boundaries, they are best considered together as a single community, Littoral Strand. The seaward margin of littoral vegetation is typically dominated by herbaceous plants—grasses, sedges, and creeping vines. A zone of shrubby vegetation often occurs inland from this, and farther inland, a forest zone. A zone dominated by screwpine (*Pandanus tectorius*) also occurs on some coasts, usually just seaward of the forest called. In some cases, the trees on the seaward margin of littoral forest are wind-pruned into shrubs, especially in south- and east-facing areas exposed to the prevailing winds, making the littoral forest structurally but not floristically similar to vegetation described as littoral shrubland. The boundaries between existing vegetation types may be distinct, but more typically they are indistinct or uneven. This differentiation is not mentioned by any of the major publications on the vegetation of Guam.

Littoral Strand occurs only at the two beach sites, the Asan Beach Unit and the Agat Beach Unit, mostly at or just above sea level. The soils are usually limestone rock, which often is undisturbed because of its uselessness for human purposes, or on sand, in which case it is typically highly disturbed. It is usually converted to Managed Land Vegetation in the form of beach park lawns.

In the WAPA, the vegetation is somewhat heterogeneous, usually scrubby or herbaceous. No littoral forest occurs there, apparently only the zones corresponding to herbaceous strand and littoral shrubland. The major species listed there by Yoshioka (2008) include the trees *Casuarina equisetifolia* (ironwood), *Hibiscus tiliaceus* (beach hibiscus), *Hernandia Nymphaeifolia* (Chinese lantern tree), coconut, *Pandanus tectorius* (screwpine), and *Thespesia populnea*; the shrub *Colubrina asiatica*; the vines *Derris trifoliata* and *Ipomoea pes-caprae* (beach morning-glory); the grasses *Sporobolus virginicus* and *Thuarea involuta*; and the sedge *Fimbristylis cymosa*.

This unit may be too narrow a zone to map, and possibly too highly disturbed to distinguish it from the adjacent beach lawns. It almost certainly cannot be divided into distinct zones.

Limestone Forest Community

Prior to human occupation, Limestone Forest covered much of Guam, especially on the northern half of the island, but now most of it, particularly in the more accessible places, has been highly degraded. Pockets of it occur on the northern half of the island, and in the WAPA it is found in four of the units: Asan Beach, Asan Inland, Fonte Plateau, and Mt. Alifan. The soil is typically limestone, often limestone rock that is sometimes quite rugged (“karst”), which makes movement though it difficult, but it sometimes has a covering of ancient volcanic ash. It is sometimes called “typhoon forest,” because of its adaptations to the frequent and periodic typhoons that lash the island. In the WAPA, Limestone Forest occurs from near sea level (at Asan Beach) to 640 ft (195 m; at Fonte Plateau) elevation.

Fosberg (1960) referred to this plant community as “Forests of elevated hard limestones,” and recognized seven subtypes. Mueller-Dombois and Fosberg (1998) referred to the same vegetation type as “Forest on Elevated Limestone Plateaus and Cliffs.” Yoshioka (2008) used several terms that apparently refer to variations of this: Limestone Forest, Mixed Limestone Forest, Disturbed Limestone Forest, and Mixed Forest in Volcanic Soil on Limestone. If disturbed, it would blend into other types of vegetation, especially secondary forest, but its origin

from Limestone Forest is often detectable by its limestone rock substrate and the presence of indicator native tree species.

The climax species in this kind of forest on Guam are often *Ficus prolixa* (banyan), *Artocarpus mariannensis* (Marianas breadfruit), *Mammea odorata*, *Cordia subcordata*, *Merrillioidendron megacarpum*, and *Pandanus tectorius* (screwpine). Yoshioka listed the most common native Limestone Forest trees in the WAPA as *Pouteria obovata*, *Intsia bijuga*, *Pandanus tectorius* (screwpine), *Pandanus dubius* (another screwpine), *Psychotria mariana*, *Hernandia nymphaeifolia* (Chinese-lantern tree), *Ficus microcarpa* (a banyan), *Ficus prolixa* (another banyan), *Ficus tinctoria*, *Aglaia mariannensis*, *Neisosperma oppositifolium*, and *Xylosma nelsonii*. Yoshioka did not list the presence of the common Limestone Forest species noted above from Fosberg's (1970) discussion, and does not mention any of these species as being dominant (except the *Neisosperma* in one place), so presumably most of these forest areas are disturbed and with alien species, such as *Artocarpus altilis* (breadfruit), *Leucaena leucocephala* (tangentan), and *Triphasia trifolia* (limeberry), being common.

Limestone Forest, because of its short stature, does not usually have a closed canopy and layers, but in some places there is "an obvious subcanopy layer at 1.5 to 2.4 m (five to eight feet), characterized by immature or short-stature trees and mature shrubs such as *Colubrina asiatica*, *Leucaena leucocephala*, *Morinda citrifolia*, and *Triphasia trifolia*," according to Yoshioka. Other shrubs and small trees sometimes common include *Scaevola taccada*, *Ximenia americana*, *Polyscias grandifolia*, *Premna serratifolia*, *Timonius nitidus*, *Psychotria mariana*. Vines climbing on trees in these forests include *Abrus precatorius*, *Cayratia trifolia*, *Entada phaseoloides*, *Freycinetia reineckeii*, *Piper guahamense*, and *Piper betle*.

Most or even all of these areas Yoshioka calls Limestone Forest may be disturbed, making it difficult to distinguish from secondary forest. It is not clear if the four types of Limestone Forest listed by Yoshioka—Limestone Forest, Mixed Limestone Forest, Disturbed Limestone Forest, and Mixed Forest in Volcanic Soil on Limestone—will be recognizable and mappable as distinct units.

Ravine Forest Community

This is a type of forest found on volcanic soils on the southern part of Guam. It probably comprises remnants of a more extensive forest that covered most of this southern portion of the island before the arrival of the Chamarros, but because of extensive disturbance during the centuries of occupation, it now is found only in the moister gulches, valley bottoms, and steep slopes. Savanna predominates between these remnants. This forest was recognized as Ravine Forest by (Fosberg 1960), who characterized it as forest occurring "mainly on volcanic, argillaceous, or limestone soil on the southern part of Guam." Mueller-Dombois and Fosberg (1998) referred to it as "Ravine Forest on Volcanic Soil and on Limestone Outcrops in Valleys," which is basically the same name. Yoshioka (2008) referred to it by two different names, "Ravine Forest" and "Mixed Ravine Forest," presumably distinguished by the amount of disturbance. The tree stature of Ravine Forest is low, and characteristic species include *Hibiscus tiliaceus*, *Pandanus tectorius* (screwpine), *Pandanus dubius* (another screwpine), *Ficus prolixa* (a banyan), *Glochidion mariannensis*, and *Premna serratifolia*. It is generally similar to Limestone Forest, but tends to be thicker, lower, bushier, and characterized by the presence of *Areca catechu* (betel nut) palms, and of course, occurs on a different substrate.

Yoshioka reported Ravine Forest to occur in the WAPA in two of the units, Mount Chachao-Mount Tenjo and Asan Inland. In the Mount Chachao-Mount Tenjo Unit, it is limited to the upper elevation headwaters of Yling River on the slopes of Mount Tenjo from 830 to 900 ft (250–275 m) elevation. It occurs in the Asan Inland Unit as “Mixed Ravine Forest” in valleys or gulches below 500 ft (150 m) elevation that are watered by perennial streams and rivers that emerge from springs at the headwaters. Yoshioka recognized two subtypes of the latter. One type is found in gulches that includes transition vegetation from the savanna to riparian systems along rivers, and is what she refers to as Ravine Forest. She noted the dominance of non-native trees, such as the alien palm *Heterospathe elata*; native shrubs, such as *Melochia villosissima*; native vines, such as *Jasminum marianum*; and several native grasses, including *Miscanthus floridulus* (swordgrass) and *Phragmites australis* (which she calls *P. karka*). The other ravine forest community was associated with habitation and reflected recent, and possibly historical, plantings of non-invasive ornamentals such as *Heliconia bihai*, *Alpinia purpurata*, *A. zerumbet*, *Costus speciosus*, and *C. woodsonii*. Mangoes and coconuts are also found here, growing along the river’s edge. Fruits, flowers, and foliage are apparently periodically harvested from these plants, making the area something of an agroforest.

Because of the heavy disturbance to the area, there are no real canopy or layers. Some of the low stature trees and shrubs reported by Yoshioka from the Mount Chachao-Mount Tenjo Ravine Forest (which she noted was “somewhat disturbed”) were *Ficus prolixa* (a banyan), *Ficus tinctoria*, *Hibiscus tiliaceus* (beach hibiscus), *Casuarina equisetifolia* (ironwood), *Cycas circinalis* (cycad), *Melochia villosissima*, and *Pandanus tectorius* (screwpine). Common alien trees included *Vitex parviflora* and the palm *Heterospathe elata*. Terrestrial ferns are common, especially the native species *Phymatosorus grossus*, *Thelypteris opulenta*, and *Angiopteris evecta*. Some common non-natives include *Eupatorium odoratum* and *Mikania micrantha* (mile-a-minute vine), both of which are common weeds on Guam.

Two other terms related to vegetation occurring along streams were recorded by Yoshioka (2008). “Riparian Community” comprises the vegetation that occurs on the banks of streams. This often differs from the adjacent or surrounding vegetation because the wet soil there often supports a different flora, one that is adapted to the wet conditions (e.g., swamp forest trees). However, this often comprises a very narrow zone, and because it is often highly disturbed, it might be better classed with disturbed types of vegetation. Yoshioka used this term for the streamsidess in the Piti Guns Unit, but for the Asan Inland Unit and the Mt. Alifan Unit, she used instead “Riverine Community.” This is probably just a mistake in terminology, and the two are probably synonymous.

It is not clear how these two terms are related to the Ravine Community described elsewhere in her report. It might correspond to Fosberg’s (1960) “Swamp” category, especially the subtype “Riverine,” but is more of a streamside margin of swamp forest trees rather than an actual swamp. Yoshioka’s Riparian and Riverine Vegetation types are probably best considered as a subset of Ravine Forest.

***Phragmites* Marsh Association**

This is an association of the Marsh Community that is usually entirely dominated by the reed *Phragmites australis* (formerly called *P. karka*). It was recognized by Fosberg (1960) as “Type 3—Marshes,” and of this, the “subtype a, reed marsh, dominated by *Phragmites karka*.”

However, it also fits into “Type 6—Savannas, subtype d, “*Phragmites karka* valleys, dominated by the reed *Phragmites karka*,” because the dominant species in the two are the same. This reed frequently dominates in wet soil in open places, so perhaps the latter type of vegetation is just on wet soils on the Savanna. It corresponds to Mueller-Dombois and Fosberg’s (1998) “Reed Marsh with mostly *Phragmites karka*.” Yoshioka (2008) mentioned this type of vegetation only peripherally in her discussion of “Riverine Community” in the Mt. Alifan Unit of the WAPA.

It is entirely dominated by the tall reed *Phragmites australis* (formerly known as *P. karka*) that excludes nearly all other species. It occurs mostly in moist soils and shallow water, so in the WAPA it may be found in the Ravine Forest Community anywhere in wet areas lacking a tree canopy. Yoshioka also mentioned a large population of the tall alien grass *Tripsacum laxa* in the lower reaches of the east branch of the Asan River, but this is probably best classified as Managed Land Vegetation since there is no indication that the soil is marshy.

Savanna Community

This is the low, herbaceous or scrubby vegetation dominated by grasses, ferns, pioneer herbaceous species, shrubs, and/or small trees. It is maintained in a perennially disclimax state by periodic fires that ravage the area. This community was called “Savanna,” by Fosberg (1960), who recognized four subtypes: *Miscanthus* Community, dominated by *Miscanthus floridulus* (swordgrass); *Dimeria chloridiformis* Community, dominated by that grass; Erosion Scar Community, dominated by pioneer species, such as *Dicranopteris linearis* (false staghorn fern), *Casuarina equisetifolia* (ironwood), *Myrtella bennigseniana*, and many other shrubby species; and *Phragmites karka* Valleys, dominated by the reed *Phragmites australis*. Mueller-Dombois and Fosberg (1998) called this type of vegetation as “Savanna Complex,” and Yoshioka (2008) referred to it as “Savanna” at two sites and “Savanna Complex” at two others. The four “communities” of Fosberg are better referred to as “associations,” as they are commonly referred to in the literature elsewhere in the Pacific.

Savanna is a common type of vegetation in the Pacific, even in places like Fiji and Tonga, where it is sometimes called “talasinga.” It does not, however, correspond to the savanna vegetation of Africa, which has an entirely different origin. In Micronesia, it is best developed in the Marianas and Guam (the southern part), but is missing from many of the islands to the east. In the WAPA, it is found in four of the seven units: Asan Inland, Piti Guns, Mount Chachao-Mount Tenjo, and Mt. Alifan. Savanna ranges from 40 to 880 ft (12–268 m) in elevation.

Savanna covers hills and slopes on old volcanic soils (often red clay) and is believed to be mostly the result of repeated burnings over the centuries, which destroy the organic material of the soil, kill susceptible species, and select for hardy species (called “pyrophytes”) that are able to withstand the periodic burning. Expanses of exposed soil and large areas of bedrock, locally called “badlands,” are also found here. The burning typically results in grasslands dominated by one or more of several different grass species, ferns, and shrubs or small trees, as well as alien pioneer species. If left unburned for many years, savannas are often invaded by *Casuarina equisetifolia* (ironwood), but when fires erupt, these trees are usually killed. It is not clear what kind of vegetation would result if the burning were entirely eliminated, since possible successors are not listed in the current vegetation schemes, but it might be ironwood forest.

The predominant life forms on the savanna are herbaceous (ferns, grasses, herbs) or woody (shrubs, small trees) plants, so there are no canopy or subcanopy trees that characterize many

forests. The possible exception is scattered ironwood trees found at some of the sites, but these trees are susceptible to fires, which kill them. The predominant species are typically grasses, including the large alien species *Pennisetum polystachion* (mission grass) and *Saccharum spontaneum* (wild cane), and the native species *Dimeria chloridiformis* and *Miscanthus floridulus* (swordgrass). *Phragmites australis* (formerly called *Phragmites karka*) sometimes forms dense associations in gullies and other places with wet soil. These grasses sometimes form distinct associations, as noted by Fosberg (1960), who referred to them as “communities.” Other less common and smaller, mostly alien grasses found in savanna include *Chrysopogon aciculatus*, *Sporobolus diander* (dropseed), and *Eragrostis tenella* (love grass). Common small sedges include *Rhynchospora rubra*, *Scleria polycarpa*, and *Fimbristylis tristachya*. Other common herbaceous, mostly alien species include the alien orchids *Arundina graminifolia* (bamboo orchid), and *Spathoglottis plicata* (Philippine ground orchid), and the herbs *Alysicarpus vaginalis*, *Bidens alba* (beggar’s tick), *Cassytha filiformis*, *Crotalaria retusa* (rattlepod), *Elephantopus mollis* (elephant’s foot), *Passiflora foetida* (love-in-a-mist), *Stachytarpheta jamaicensis* (Jamaica vervain), and *Waltheria indica*. Ferns are sometimes a dominant component of savanna vegetation, especially *Lindsaea ensifolia*, *Lygodium microphyllum*, *Nephrolepis hirsutula* (swordfern), *Blechnum orientale*, *Lycopodiella cernua*, and *Dicranopteris linearis* (false staghorn). In many places in the Pacific, the latter fern is the overall savanna or “fernland” dominant, but Yoshioka (2008) reported it only to be “common” rather than “abundant” at the four sites.

Shrubs and small trees are sometimes common on savanna, especially when fires have not recently occurred. The most common of these woody species are native species *Glochidion marianum*, *Timonius nitidis*, *Premna serratifolia*, *Melastoma malabathricum* var. *marianum*, *Scaevola taccada*, and *Morinda citrifolia*, and the alien tree or shrub *Leucaena leucocephala*.

Although Fosberg divided his savanna vegetation into four subtypes, it may not be practical to divide it any further into associations in the WAPA, since these associations are temporary, and major changes occur after fires.

Mahogany Forest Association

This type of vegetation comprises a plantation forest of mahogany (*Swietenia macrophylla*) trees. Yoshioka (2008) noted its presence in the southwestern quarter of the Piti Guns Unit at somewhere between ca. 40 to 340 ft (12–104 m) on volcanic soil (the predominant type in this end of the island). It is mono-dominant (i.e., it has one species dominance) because the canopy is dominated by the mahogany trees that were planted there. When mature, the trees produce a dense canopy and resultant shady understory. The sparse subcanopy comprises short native trees and shrubs, especially *Glochidion marianum* and *Scaevola taccada* in shaded areas. In sunny areas under canopy gaps, the alien grasses *Saccharum spontaneum* (wild cane) and *Panicum maximum* (Guinea grass) dominate. In the shaded areas, the ground is dominated by a dense cover of shade-tolerant ferns, both native and non-native species, especially *Nephrolepis biserrata*, *Christella parasitica*, *Phymatosorus grossus*, and *Thelypteris opulenta*. Other groundcover plants include *Cyperus* spp. and many *Leucaena leucocephala* (tangentangan) seedlings. Yoshioka also noted the presence of a “transition area,” the most common species of which are the herb *Tacca leontopetaloides* (Polynesian arrowroot); the alien grass *Imperata conferta*; and the native trees and shrubs *Timonius nitidus*, *Morinda citrifolia* (Indian mulberry), *Casuarina equisetifolia* (ironwood), and *Leucaena leucocephala*.

This type of vegetation covers only a small part of the WAPA. It does not fit well in the categories in Fosberg (1960), perhaps most approximating his “Coconut Groves” category, but of course with a different dominant species. Less likely, his “Weed Communities” category. It probably best fits into Mueller-Dombois and Fosberg’s (1998) “Urban Cultivated” category, which was described as easily distinguishable in satellite photos “by the general absence of forest cover, and the presence of large or conspicuous food-producing trees, such as bananas, coconuts, breadfruit, and mangoes.” (The part about absences of forest cover does not fit, however.) The mahogany forest was planted on very disturbed land (a former quarry), which, prior to human occupation, was probably covered with a type of lowland forest characteristic of volcanic soils on Guam.

Managed Land Vegetation (Lawns)

Managed land vegetation comprises the areas that are under periodic or frequent management, such as the edges of roads, pastures, lawns, and orchards. The vegetation here is not allowed to come into equilibrium with the environment, i.e., it does not change with time into a vegetation type that is semi-permanent. It is prevented from doing so by management in the form of mowing, plowing, weeding, or herbivore grazing. Nearly all the species comprising its flora are alien lawn species, because most of the native species disappeared along with their habitat. This vegetation fits into Fosberg’s (1960) “Weed Community” category, and into two of Mueller-Dombois and Fosberg’s (1998) categories, “Predominantly Open Ground and Pastures” and “Urban Vegetation around Military Installations and Cities.” Yoshioka (2009) described it as “Lawn” and “Maintained Lawn.”

The lawns in this category are found in the Asan Beach Unit and the Agat Unit, both of them on the shore near sea level on beach sand soil. The Managed Land Vegetation at the Asan Beach Unit comprises a lawn that is mowed frequently. The most common species here are *Cynodon dactylon* (Bermuda grass), *Digitaria* spp., *Sporobolus* spp., *Stenotaphrum* sp., *Wedelia trilobata* (wedelia), *Tridax procumbens* (coat buttons), *Alysicarpus vaginalis*, and *Desmodium triflorum* (beggarweed). Large ornamental trees are also maintained in the lawn area. These include coconut, *Calophyllum inophyllum* (Alexandrian laurel), *Peltophorum pterocarpum* (yellow poinciana), *Samanea saman* (monkeypod), and others.

The Agat Unit Managed Land Vegetation also comprises lawns and surrounding vegetation. The most common grasses include *Axonopus compressus* (carpetgrass), *Cenchrus echinatus* (burr grass), *Chloris barbata* (swollen fingergrass), *Chrysopogon aciculatus* (golden beardgrass), *Cynodon dactylon* (Bermuda grass), *Dactyloctenium aegypticum* (beach wiregrass), *Dichanthium bladhii*, *Digitaria violascens* (violet crabgrass), *Eleusine indica* (goosegrass), and *Thuarea involuta*, all but the last one of which are alien species. Alien herbs, such as *Desmodium triflorum* and *Phyla nodiflora*, were also found in the frequently mowed lawn. There are several ornamental and food species in the lawn area of Gaan Point, including *Mangifera indica* (mango), *Pithocellobium dulce* (Manila tamarind), coconut, and *Averrhoa bilimbi* (pickle tree).

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**PART 2. AMERICAN MEMORIAL PARK (AMME),
SAIPAN, COMMONWEALTH OF THE NORTHERN MARIANAS**

INTRODUCTION

Saipan is the largest island and capital of the United States Commonwealth of the Northern Mariana Islands (CNMI), a chain of 15 tropical islands (the Marianas archipelago) in the western Pacific Ocean with a total area of 45 mi² (115 km²). The island is located at latitude of 15.25° N and longitude of 145.75° E, about 120 mi (190 km) north of Guam. Its western side is lined with sandy beaches and an offshore coral reef that creates a large lagoon. The eastern shore is composed primarily of rugged rocky cliffs and a reef. The island's highest point is a limestone covered mountain called Mt. Tapochau at 1560 ft (480 m). The 2000 census population of Saipan recorded over 62,000 inhabitants.

American Memorial Park is located on 133 acres (54 ha) of land on the western side of Saipan. Established in 1978, it commemorates American soldiers who lost their lives in the campaign on Saipan during World War II. Bordering the AMME is Micro Beach, one of Saipan's finest white sand beaches and which provides a view of Managaha Island and dramatic evening sunsets. Within the AMME is a 30-acre (12 ha) wetland comprising mudflats, marshes, and mangroves, a remnant habitat now quite scarce in the Northern Marianas. The wetland is an excellent environment for native bird species including some endangered species.

GEOLOGY

Saipan is a part of the Mariana Island Arc System, where the Pacific plate is being subducted under the Philippine plate. It had its beginning about 42 million years ago in an area to the west called the Palau-Kyushu Ridge. Between that time and the present, the island and the chain have undergone eastward movement, volcanic activity, uplift and subsidence with attendant reef formation, and erosion by wind, rain and movements of the sea. Although the island is volcanic in origin, it is almost entirely covered with uplifted limestone from ancient coral reefs; these episodically uplifted limestone terraces create a flat "layer-cake" topography with numerous caves, both above and below sea level. Contained within the rock formations are three volcanic cores, numerous fault lines, and layered volcanic and calcareous rocks (Cloud et al. 1956). The west coast of the island south from the Magpi benches consists of an almost continuous calcareous sand beach backed by a few low limestone ridges and underlain by Tagpochau limestone formed in the early Miocene.

The high point of the island, Mt. Tapochau, appears to be an extinct volcano, but is, in fact, a limestone formation. To the north of it towards Banzai Cliff lies a ridge of hills, and Mount Achugao, situated about 2 mi (3 km) to the north, is a remnant of a stratified composite volcanic cone whose Eocene (15–20 million years ago) center was not far north of the present peak. Much of the island surface is karst, with numerous sinkholes, caves, and springs. The U.S. Geological Survey (USGS) is revising the geologic map of Saipan.

CLIMATE

Saipan lies within the humid tropics with tropical marine, hot and humid oceanic climate characterized by relative high and uniform temperatures moderated by seasonal northeast trade winds. The NE and ENE trade winds are persistent during the January to May dry season whereas winds from various directions are less strong, and sporadic, during the rainy season, which runs from about May through December. The annual mean temperature is 83° F (28° C), with a seasonal variation in mean monthly temperature of less than 3.5 F (2° C). However, temperature is affected by elevation, so there are considerably greater temperature variations between the coastal and mountainous areas. Humidity is very high with monthly averages between 79 and 86 %, but fresh breezes provide a measure of comfortable relief. The months of greatest humidity are July to November. The mean annual rainfall is approximately 84 inches (2130 mm), but rainfall varies from year to year. Sometimes the islands experience droughts generally during the period from December through June. The wet season is from July through October.

The island is situated some 600 mi (960 km) east of an area in the western Pacific that is the breeding grounds for cyclonic disturbances. As a result, it is in what is known as weather condition four at all times which means that 40 mph (64 kph) winds are possible within 72 hours. These cyclonic disturbances can quickly and sometimes unexpectedly develop into typhoon force winds of 120 mph (192 kph) or greater. An average of 31 tropical storms develop in the western north Pacific every year with typically one or more affecting Saipan. Over 16 typhoons have hit nearby Guam since 1970. The strong winds wreak havoc on the vegetation, creating forests dominated by relatively short trees that are best suited to withstand the effects of the storm.

FLORA

Very little has been written about the flora of Saipan, unlike that of the neighbor island of Guam. Apparently no flora or history of collections from the island has ever been published. Some of the largest collections were made in Saipan by F.R. Fosberg, who was the most significant and prolific collector in Micronesia from the 1950s through the 1980s. The most up-to-date work on the flora of Saipan can be extracted from the publications of Fosberg et al. (1979, 1982, and 1987), which includes all of Micronesia. There have been only minor publications on the plants since then, including one on orchids (Raulerson and Rinehart 1992) and one on the trees and shrubs (Raulerson and Rinehart 1991) of the Marianas, which includes Saipan. Vogt and Williams (2004) published a book on the flora of the Marianas, but this book has been little publicized. From data extracted from the Fosberg et al. publications, it is estimated that the flora of Saipan includes about 165 native angiosperms, 28 native ferns and fern allies, and one gymnosperm (a cycad). These totals are based on the Principal Investigator's evaluation of which of the species on the lists are actually native.

In a study of the flora and vegetation of the AMME was done by Raulerson and Rinehart (1989), 128 species of vascular plants were recorded in the AMME, thirteen (10%) of which are ferns and fern allies. The remaining 115 species were flowering plants, with no gymnosperms present. Fifty-six species (44%) are indigenous, none endemic to the Marianas. Of this total, 72 (56%) are alien species, 67 (78%) of which are naturalized. There are no federally endangered plant species present.

VEGETATION

Information on the vegetation of Saipan can principally be found in Fosberg's (1960) *Vegetation of Micronesia*. Fosberg did not divide the vegetation into communities or associations, because he was descriptive rather than classificatory. He noted "Scarcely an acre of the island has not been profoundly disturbed. As a result the vegetation pattern is neither simple nor stable." The original forest that covered nearly all the island before human occupation some 3500 years ago was probably a Mixed Limestone Forest. In the remnants still existing today, and typical dominant species include *Cynometra ramiflora*, *Erythrina variegata*, and *Barringtonia asiatica* (fish-poison tree). Other native species present noted by Fosberg include *Pandanus tectorius* (screwpine), *Pandanus dubius* (another screwpine), *Pisonia umbellifera*, *Neisosperma oppositifolium*, *Ochrosia mariannensis*, *Ficus* spp., *Pouteria obovata*, *Dendrocnide latifolia*, *Guamia mariannae*, *Melanolepis multiglandulosa*, *Claoxylon marianum*, *Aglaia mariannensis*, *Hibiscus tiliaceus* (beach hibiscus), and *Aidia racemosa*. Where this forest approaches the coast, the trees become stunted, and species, such as *Scaevola taccada*, *Jasminum marianum*, and *Psydrax odoratum*, become abundant. In the most exposed places, *Pemphis acidula*, *Scaevola taccada*, and *Hedyotis* spp. tend to dominate. In open places on the coast, the dominant species of herbaceous vegetation are often *Zoysia matrella*, *Stenotaphrum micranthum*, and *Phyllanthus marianus*.

Most of the level land on Saipan was put under sugar cane cultivation by the Japanese, and hence little if any of the native mixed limestone forest remains on it. When not tended for a while, it soon goes back to secondary scrub dominated by species, such as *Hibiscus tiliaceus* (beach hibiscus) and *Melochia* spp., or by grasslands dominated by *Saccharum spontaneum* (wild sugarcane), *Pennisetum purpureum* (elephant grass), and other grasses and weedy dicots. In other areas, alien trees such as *Casuarina equisetifolia* (ironwood), *Albizia lebbek*, *Pithecellobium dulce* (Manila tamarind), and *Acacia confusa* dominate. Some of the former sugarcane land is now farmed by Saipanese. In some wet places, *Phragmites australis* or *Brachiaria mutica* (California grass) form dense brakes.

Savannas often occur on volcanic surfaces. These are typically dominated by the reed *Miscanthus floridulus*, but if not burned for a long time, *Casuarina equisetifolia* (ironwood) trees may become common. In eroded savanna, the dominant species are typically *Dicranopteris linearis* (false staghorn fern), with lesser amounts of *Chrysopogon aciculatus* (golden beardgrass), *Heteropogon contortus*, *Scaevola taccada*, *Dendrolobium umbellatum*, and other ferns, herbs, and shrubs.

A more comprehensive vegetation scheme, of all of the Pacific Islands, was published by Mueller-Dombois and Fosberg (1998). It included a general description of the vegetation types in Micronesia, and a more specific discussion of each of the islands. They divided the vegetation of Saipan into four types: Primary Vegetation on Limestone; Secondary Vegetation on Coastal Plains; Vegetation on Old Volcanic Soils; and Strand Vegetation.

The first category, Vegetation on Limestone, and the third one, Vegetation on Old Volcanic Soils do not need to be considered further since they are not found in AMME. Secondary Vegetation on Coastal Plains includes vegetation types such as Secondary Scrub, Secondary forest, and Managed land vegetation as used in the recent literature. It is on land that has been highly disturbed for centuries. The category is not further divided, but the variation of forms such swamps, marshes, and gardens are briefly discussed. Strand vegetation includes the Littoral Strand as recognized elsewhere in the literature, but also includes mangroves.

In their botanical survey of the AMME, Raulerson and Rinehart (1989) noted the presence within the “natural area” of mangrove swamps, marshes, strand, coastal scrub, and weedy scrub, although it is not clear how the latter category can be a “natural area.” They did not actually divide the vegetation into communities and associations, but instead ran transects. However, they produced a map of the vegetation with the twelve following categories reorganized from the original order on the vegetation map to put similar categories together:

- (1) Closed wet mixed forest with mangroves
- (2) Closed hibiscus forest
- (3) Open wet ironwood forest with other native trees and an understory of *Acrostichum aureum*
- (4) Open wetland with *Acrostichum aureum*
- (5) Open wetland with native herbs
- (6) Closed mesic native shrubs
- (7) Closed mesic tangantangan scrub with vines
- (8). Closed mesic ironwood; kamachile forest
- (9) Open mesic ironwood forest with grassland and morning glory vine understory
- (10) Open mesic grassland with morning glory vines
- (11) Open dry area with mixed grasses (mown areas)
- (12) Planted ornamentals

These categories are discussed below in the following communities where they have been placed based on similarities: Mangrove Community; Swamp Forest Community; Freshwater Marsh Community; Littoral Strand Community; Secondary Scrub Community; Secondary Forest Community; and Managed Land Vegetation Community.

Littoral Strand Community

This community probably comprises the of the vegetation category listed on Raulerson and Rinehart’s vegetation map as **(6)** closed mesic native shrubs. It does not fit into any of the categories of Mueller-Dombois and Fosberg. It would, however, probably be best put into “Secondary Vegetation on Coastal Plains” but the latter authors’ discussion of this makes no specific mention of this kind of vegetation.

In their discussion, Raulerson and Rinehart apparently call this type of vegetation “coastal scrub,” and briefly describe it: “The coastal scrub is a combination of species that are early colonists, and those that will be later climax vegetation. The jetties where this vegetation type occurs are dominated by brushy plants such as *Eupatorium odoratum*, *Pluchea indica*, *P. carolinensis*, hunig (*Tournefortia argentea*), nanaso (*Scaevola taccada*), *Indigofera suffruticosa*, *Desmanthus virgatus*, banago, and gasoso (*Colubrina asiatica*). There is also an impressive stand of *Dodonaea viscosa* in a place quite unusual for this species. However, it is extending itself and appears to be a successful colonizer although the storms may be detrimental to its continued survival in the area.” They also noted “The weedy scrubland occurs on scraped limestone over which there is a veneer of “soil.” It is dominated by a variety of grasses, the sedge nutgrass (*Fimbristylis cymosa*) and various herbs such as *Desmodium* spp., *Polygala paniculata*, and hunig tasi (*Heliotropium procumbens*). This area is a highly artificial man-induced environment.” Because of the mixture of species and absence of clear boundaries, it

might be difficult to map these when boundaries are indistinct, the areas are small, and the difference in the species composition so blurred.

Judging by the species composition of this “coastal scrub” that only occurs along the jetty, it appears to be best categorized as disturbed Littoral Strand, because of the presence of *Tournefortia argentea* (tree heliotrope), *Scaevola taccada*, and *Colubrina asiatica*; and Managed Land Vegetation, because the remainder of the species are all weedy alien species. Part of the Marsh Community (below) has a component of littoral species, including the typical littoral trees *Hernandia nymphaeifolia* (Chinese-lantern tree) and *Thespesia populnea*; the large coastal (alien) herb *Hymenocallis littoralis* (spider lily); and the native vines *Ipomoea macrantha* and *Mucuna gigantea*, which are typical strand species.

Littoral Strand is often not homogeneous since several zones, differing in life form and flora, can sometimes be distinguished. Some authors classify these zones into plant communities because of the difference in physical structure and flora, but because of their narrow extent, their commonalities, and the indistinct boundaries, they are best considered together as a single community, Littoral Strand. The seaward margin of undisturbed littoral vegetation is typically dominated by herbaceous plants—grasses, sedges, and creeping vines. A zone of shrubby vegetation often occurs inland from this, and farther inland, a forest zone. A zone dominated by screw pine (*Pandanus tectorius*) also occurs on some coasts, usually just seaward of the forest called. In some cases, the trees on the seaward margin of littoral forest are wind-pruned into shrubs, especially in south- and east-facing areas exposed to the prevailing winds, making the littoral forest structurally but not floristically similar to vegetation described as littoral shrubland. The boundaries between existing vegetation types may be distinct, but more typically they are indistinct or uneven.

Mangrove Community

This vegetation does not fit into any of the categories of Mueller-Dombois and Fosberg. It would probably be best put into “Secondary Vegetation on Coastal Plains,” but their discussion of that category makes no mention of mangroves. It fits into Raulerson and Rinehart’s (1) “Closed wet mixed forest with mangroves.” The mangrove swamp at the AMME occurs in wet saline areas along the coast at sea level, and is dominated by *Bruguiera gymnorhiza* (oriental mangrove). The oriental mangrove is the only mangrove species in the AMME (and Saipan). *Hibiscus tiliaceus* (beach hibiscus) is often common along its edge, as it is in several other communities on Saipan. (It is a facultative wetland tree.) Also present is *Casuarina equisetifolia* (ironwood), but this is not a wetland species and is confined mostly to sandy areas above standing water. There is no shrub layer, but the ground is often covered with *Acrostichum aureum* (swamp fern), which is able to tolerate a moderate amount of salinity and thus tends to be a feature of mangrove swamps in the Marianas and elsewhere. Few other terrestrial species can survive in the saline soil. This swamp should be easy to map because of the dominance of the large mangrove trees. Mangroves do not occur at either of the other two parks in this study, The National Park of American Samoa (NPSA) and The War in the Pacific National Historical Park (WAPA) on Guam.

Freshwater Swamp Community

This community comprised areas where trees that are able to grow and thrive in standing water or where the soil is usually or continually saturated with fresh water. These wet conditions prevent most trees from becoming established or thriving here. The community differs from the Mangrove Community because, unlike mangrove trees, the component trees are not able to survive in saline water. The flora is entirely different as well. This vegetation does not fit into any of the categories of Mueller-Dombois and Fosberg. It would probably be best put into “Secondary Vegetation on Coastal Plains,” but their discussion of this makes no mention of swamps. It fits into Raulerson and Rinehart’s (2) “Closed hibiscus forest” and possibly (3) “Open wet ironwood forest with other native trees and an understory of *Acrostichum aureum*.” Both of these occur in wet soil near sea level. The former one occurs on the margins of the mangroves, and is entirely dominated by *Hibiscus tiliaceus* (beach hibiscus). It is clearly a freshwater swamp. The latter one occurs on the margins of the other wetlands, and although the dominant tree, *Casuarina equisetifolia* (ironwood) is not a wetland species, the understory is dominated by the *Acrostichum aureum* (swamp fern), which is. Also, its title includes the word “wet,” reinforcing its probably inclusion in the Freshwater Swamp Community. No shrub layer is present, but in one of them *Acrostichum aureum* is common on the forest floor. This vegetation is most similar to the Ravine Forest community in the WAPA on Guam.

Freshwater Marsh Community

This herbaceous wetland vegetation was noted by Raulerson and Rinehart to comprise two types (on their vegetation map legend), (4) “open wetland with *Acrostichum aureum*” and (5) “open wetland with native herbs.” These vegetation categories do not fit into any of those of Mueller-Dombois and Fosberg. They would probably be best put into “Secondary Vegetation on Coastal Plains” but the latter authors’ discussion of this makes no mention of marshes. In the WAPA on Guam, it comes closest to the *Phragmites* Marsh Association, which belongs to the same community (Marsh), but a different association (i.e., different dominant species). These wetlands are found near sea level in soil saturated by fresh or brackish water, which excludes most species from growing in it. The area of “open wetland with native herbs,” which lies at the southwest portion of the interior of the AMME, is described as being a small marsh vegetated with *Paspalum vaginatum* (saltgrass) and edged by *Scirpus littoralis* and *Acrostichum aureum* (swamp fern). This is a typical coastal marsh because all three are marsh species, but Raulerson and Rinehart note the presence of the typical littoral trees *Hernandia nymphaeifolia* (Chinese-lantern tree) and *Thespesia populnea*; the large coastal (alien) herb *Hymenocallis littoralis* (spider lily); and the native vines *Ipomoea macrantha* and *Mucuna gigantea*, which are typical strand species. They noted that “The presence of these strand species in the swamp is simply the result of proximity to the shoreline and the sandy substrates which predominate within the study area because of bulldozing.” Also mixed in with it, however, is the small alien tree *Leucaena leucocephala* (tangantangan), *Mikania micrantha* (mile-a-minute), *Ipomoea indica*, and *Momordica charantia*, which are weedy species that show the extent of disturbance to this area. This mixture of species makes this area difficult to map and categorize, since the presence of littoral species are typical of a Littoral Strand community and the weedy alien species are typical of disturbed vegetation. Raulerson and Rinehart do not mention, other than in the legend of vegetation map, the “open wetland with *Acrostichum aureum*”, but this is a typical marsh species, also found as an understory in open Mangrove Forest.

Secondary Scrub Community

This community comprises the vegetation category listed on Raulerson and Rinehart's vegetation map as **(7)** closed mesic tangantangan scrub with vines. It does not fit into any of categories of Mueller-Dombois and Fosberg. It would probably be best put into "Secondary Vegetation on Coastal Plains" but the latter authors' discussion of this makes no mention of this type of vegetation. Secondary scrub is usually comprised of small tree and shrub species that take over after disturbance to an area ends, replacing the herbaceous weedy vegetation that follows immediately after management of the land ceases. They may be native or alien species and are eventually replaced by larger trees that comprise Secondary Forest (see below). It comprises the largest of the vegetation units included by Raulerson and Rinehart on their map, the irregularly V-shaded area between the Micro Beach Road and the West Coast Highway, on the southern boundary of the Mangrove and the Freshwater Swamp Forest. It is dominated by *Leucaena leucocephala* (tangantangan) shrubs, but the vines present are not mentioned by Raulerson and Rinehart. However, in one place in their report they state "There are a number of weed species in the area which indicate that the area has been and is still disturbed. Tangantangan, a dominant woody weed ... All the vines, such as mile-a-minute (*Mikania micrantha*), fofgu (*Ipomoea indica*) and ahgaga (*Momordica charantia*) tend to climb and provide a dense shade..." but it is not clear in their discussion if this description pertains to the Secondary Scrub or to the Marsh Community. This Secondary Scrub does not really match any of the vegetation categories recognized at the WAPA on Guam, but tangantangan scrub is common on many parts of Guam, particularly on the northern limestone end.

Secondary Forest Community

This community comprises two of the vegetation categories listed on Raulerson and Rinehart's vegetation map: **(8)** closed mesic ironwood; kamachile forest; and **(9)** open mesic ironwood forest with grassland and morning glory vine understory. These vegetation categories do not fit into any of those of Mueller-Dombois and Fosberg. They would probably be best put into "Secondary Vegetation on Coastal Plains" but the latter authors' discussion of this makes no mention of this type of vegetation. This vegetation occurs in only one place at the AMME, in a grove at the east end. Secondary Forest is usually comprised of relatively large, native or alien tree species that eventually replace Secondary Scrub as its taller trees may eventually shade out the shorter species of the latter category. In the situation where it is currently found, it could be a remnant of Secondary Forest that was left standing when the AMME was developed. It is dominated by two alien tree species, *Casuarina equisetifolia* (ironwood) and *Pithecellobium dulce* (Manila tamarind). Raulerson and Rinehart do not say anything about it in their discussion, so it is not clear what herbaceous and shrubby species occur in it, if any.

The "open mesic ironwood forest with grassland and morning glory vine understory" category occurs only along both sides of a road on the west side of the AMME. Raulerson and Rinehart do not describe this, but it appears to be dominated by *Casuarina equisetifolia* (ironwood) without a *Pithecellobium dulce* (Manila tamarind) component, and a more open structure.

Managed Land Vegetation Community

This community comprises three of the vegetation categories listed on Raulerson and Rinehart's vegetation map: **(10)** open mesic grassland with morning glory vines; **(11)** open dry area with mixed grasses (mown areas); and **(12)** planted ornamentals. These vegetation categories do not fit into any of those of Mueller-Dombois and Fosberg. They would probably be best put into "Secondary Vegetation on Coastal Plains" but the latter authors' discussion of this makes no mention of this type of vegetation.

The first category occurs in two patches contiguous with the "open mesic ironwood forest with grassland and morning glory vine understory" on the west side of the AMME. It is not further discussed by Raulerson and Rinehart, but its name indicates that it is open *Casuarina equisetifolia* (ironwood) woodland with an understory of a vine, probably *Ipomoea pes-caprae* (beach morning glory).

The "open dry area with mixed grasses (mown areas)" category occupies most of the western half of the AMME. Raulerson and Rinehart do not describe it, but it comprises regularly mowed lawns presumably dominated by grass and herbaceous species that can withstand the periodic mowing. It is virtually the same as the "Managed Land Vegetation (Lawns)" found at the beach units of the WAPA on Guam. The third category of Raulerson and Rinehart, "planted ornamentals," comprises a small area on the western half to the property next to a road. No mention is made of which species are found in it. Also not mentioned by them on the vegetation map are overgrown weedy areas. These were mentioned in conjunction of an area of marsh: "Another grassy area along the north and northwest part of the interior is not a marsh, but does get appreciable moisture; the grasses are elephant grass (*Pennisetum purpureum*) and Guinea grass (*Panicum maximum*), which are large but are not wetland species."

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