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Republic of Palau's Forest Resources: Forest Inventory and Analysis, 2014

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Cover photo: Unique forest ecosystem of Palau's Rock Islands near Koror. USDA Forest Service photo by Seth Ayotte.

Abstract

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In 2014, the U.S. Department of Agriculture Forest Service Forest Inventory and Analysis program collected forest and tree measurements from 56 forest plots among three forest communities (lowland forest, mangrove, and strand forest) in the Republic of Palau, across Babeldaob, Koror, Peleliu, Angaur, and the Rock Islands. A total of 125 tree species and 196 dominant vascular plants were recorded, most in lowland tropical rainforest. Strand forest had the lowest stem density and highest basal area and volume per acre among forest communities. The Rock Islands had the highest basal area, volume per acre, and percentage of trees >10 inches diameter at breast height, but also the highest stem density among island groups (Babeldaob, Peleliu/Angaur, or the Rock Islands).

Palau had a high percentage of forest canopy cover in 2014, with some missing canopy cover associated with wind or fire disturbance. Little evidence of damages from feral pigs or tree cutting were recorded, and no specific human disturbance was observed except for fire. About 40 percent of observed *Cocos nucifera* L. (lius) trees had

Oryctes rhinoceros beetle damage. Less than 1 percent of total forest area was covered with nonnative invasive plants, and the mean percentage of cover of the native/invasive vine *Merremia peltata* (L.) Merr. (kebeas) decreased by 17 percent compared to 2003.

Between 2003 and 2014, the average height of all trees in Palau increased by 2 feet, and the forest grew about 100,000 tons of tree biomass per year (50,000 tons of carbon). The estimates for mean diameter and stem density per acre did not change significantly, but mean basal area per acre significantly increased between inventories. Disturbed forest area increased from 1 to 25 percent, and tree damage increased by 10 percent.

KEYWORDS:

Carbon
Inventory
Micronesia
Republic of Palau

Highlighted Forest Inventory and Analysis Statistics, Republic of Palau

- Estimated total forest area: 102,130 acres
- Estimated total number of live trees ≥ 1 inch diameter
at breast height: 95,721,769
- Estimated total biomass: 8,367,644 tons
- Estimated total live aboveground tree carbon:
4,183,822 tons

Preface

U.S. Department of Agriculture Forest Service Forest Inventory and Analysis (FIA) is one of the largest ground-based forest monitoring programs in the world, continuously measuring forest structure and health across 49 of the United States and collecting forest data in Hawaii, U.S. territories, and the U.S.-Affiliated Pacific Islands about every 10 years. The FIA program began working with the U.S.-Affiliated Pacific Islands and other U.S. territories in 2001. The first forest inventory in the Republic of Palau began in 2003, and these plots were remeasured in 2014 (Agricultural Act 2014).

Differences Between 2003 and 2014 Inventories and Reports

There were some differences in the methods between the 2003 and 2014 inventories, and differences in reporting of summary results. Percentage of live canopy cover for the entire plot, and pig damage of subplot area were not measured in the 2003 inventory, and the 2003 report

did not mention percentage of forest area by disturbance, dominant species, growth habit, and canopy layer.

The topographic relative moisture index of forests in Palau was not recalculated for the 2014 report. Number of subplots, mean cover, and standard deviation for understory species and tree seedlings were listed for all species in the 2003 report, but the 2014 report only lists the 20 most common understory and tree seedling species by percentage of forest area covered.

The 2003 report listed 11 limestone forest plots in Palau but did not filter out mangrove forest in Peleliu, and strand forest was not assigned in the 2003 inventory but was present on 2 plots. If those plots were accounted for, there were only eight limestone lowland forest plots measured in the Republic of Palau, which is important for the species diversity comparison by substrate as strand and mangrove forests have lower tree species diversity per plot than lowland tropical rainforest.

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Introduction

This summary of forest resources of the islands of the Republic of Palau is based on forest inventories conducted in 2003 and 2014 by the U.S. Department of Agriculture (USDA) Forest Service Pacific Northwest Forest Inventory and Analysis (FIA) program in cooperation with Republic of Palau Division of Forestry, Bureau of Agriculture, Ministry of Natural Resources, Environment and Tourism (fig. 1). The FIA program designed the inventory to determine the status and trends of forested ecosystems, to

provide resource managers with information they can use to manage their forests, and to share forestry skills among jurisdictions and agencies. Palau's national forest action plan describes the forest resources in detail, and includes descriptions of forest types and their ecosystem services, as well as high-priority landscapes and the primary issues facing trees and forests in Palau as defined by consulted members of Palauan communities (Republic of Palau 2010). A multinational crew, including foresters from Palau, Guam, and Alaska, conducted the fieldwork for the 2014 inventory.

Republic of Palau

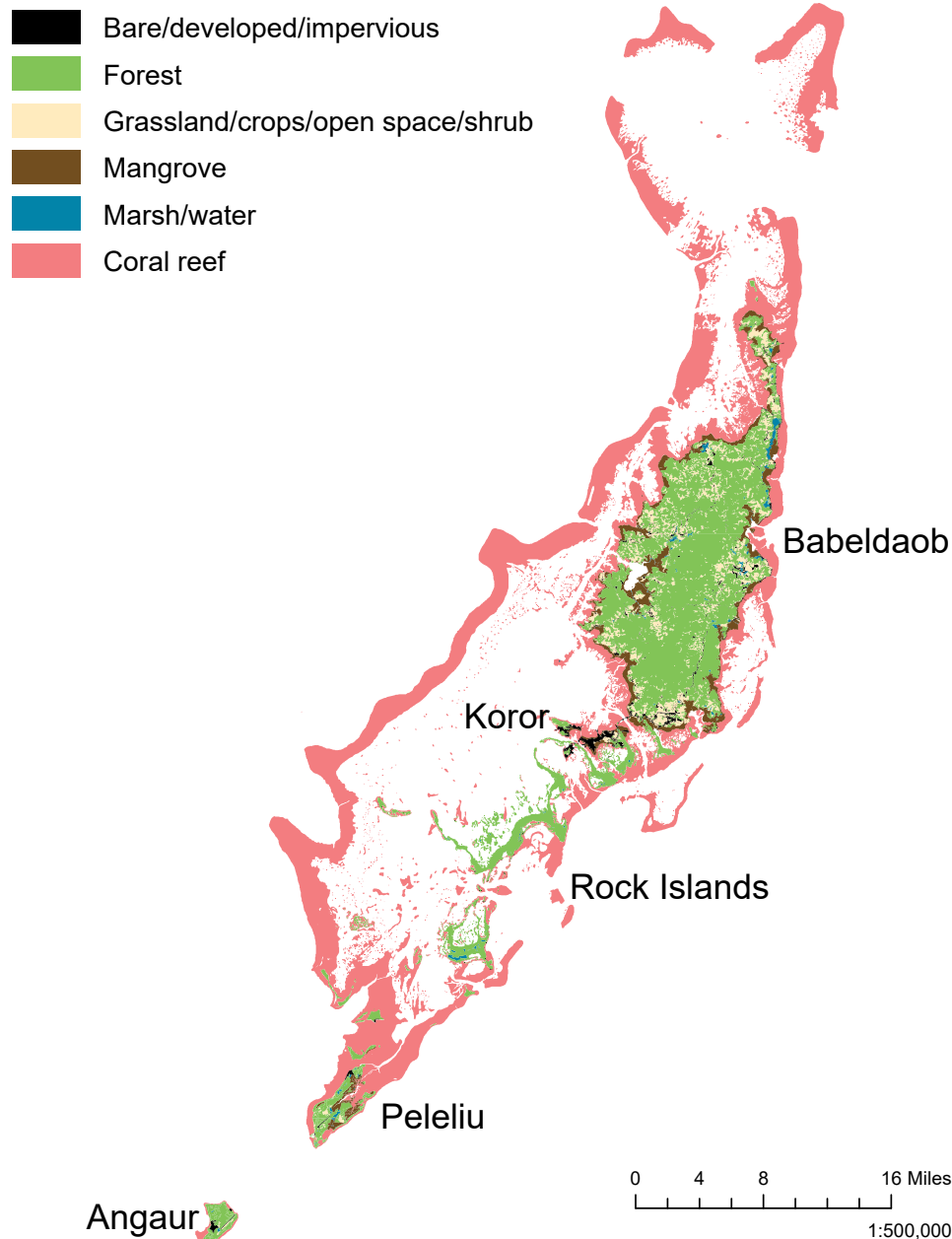


Figure 1—Republic of Palau archipelago in the tropical northwest Pacific Ocean.

Geography and Climate of Palau

Palau is a tropical archipelago at the western edge of Micronesia in the northwestern Pacific Ocean region. Palau has more than 500 islands within its main island group, of which humans inhabit about a dozen; all these islands except for Angaur are somewhat protected by a barrier/fringing reef that surrounds them (fig. 1). Palau's islands are varied by type and age, including ancient and eroded volcanic islands, such as Babeldaob and the three islands

that make up the population center of Koror; limestone platform islands with limestone ridges, such as Peleliu and Angaur; and the elevated, extremely rugged karstic Rock Islands (figs. 2–4). There are also atolls in the far north and south of the archipelago, as well as low coral sand islands in the southwest island group; however, because of their small sizes and remote locations, the forests on these islands were not sampled. The sampled areas reported in this inventory of Palau cover 98.9 percent of the total land area.

Babeldaob Vegetation and USDA Forest Service Forest Inventory and Analysis (FIA) Forest Plots

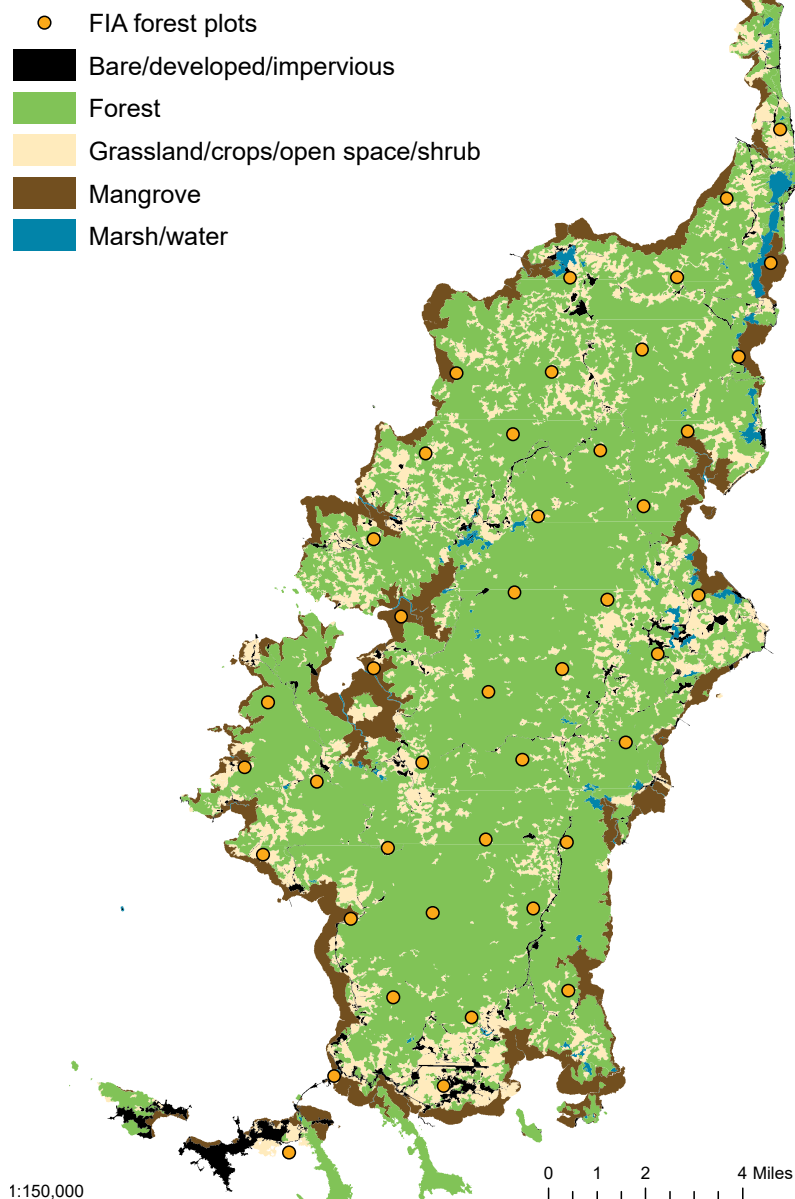


Figure 2—Republic of Palau, Babeldaob vegetation cover (2014) (USDA FS 2021) and USDA Forest Service Forest Inventory and Analysis (FIA) plots; plot locations are approximate.

Koror and Rock Islands vegetation and USDA Forest Service Forest Inventory and Analysis (FIA) forest plots

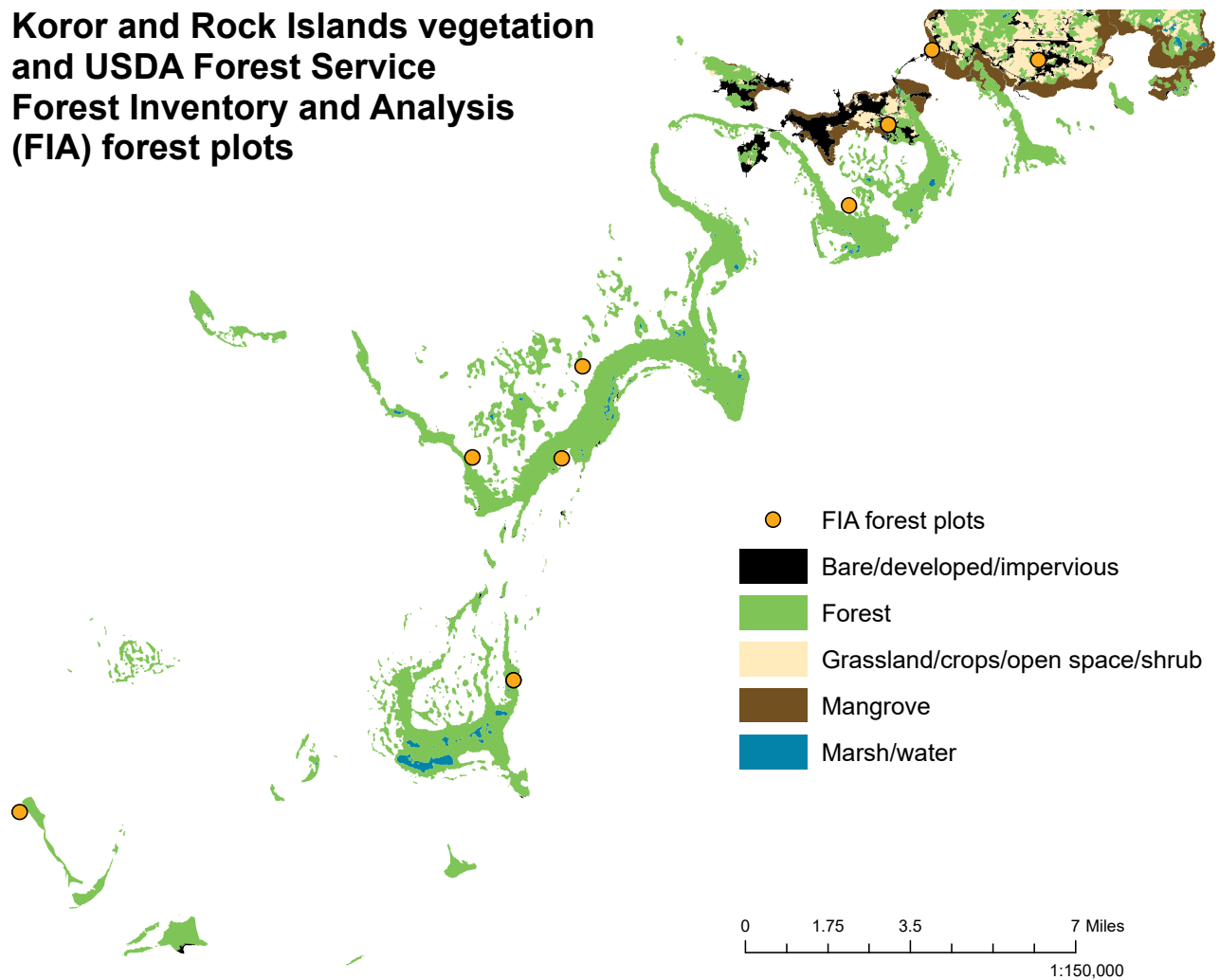


Figure 3—Republic of Palau, Koror, and Rock Islands vegetation cover (2020–2021) (USDA FS 2021) and USDA Forest Service Forest Inventory and Analysis plots; plot locations are approximate.

Peleliu/Angaur vegetation and USDA Forest Service Forest Inventory and Analysis (FIA) forest plots

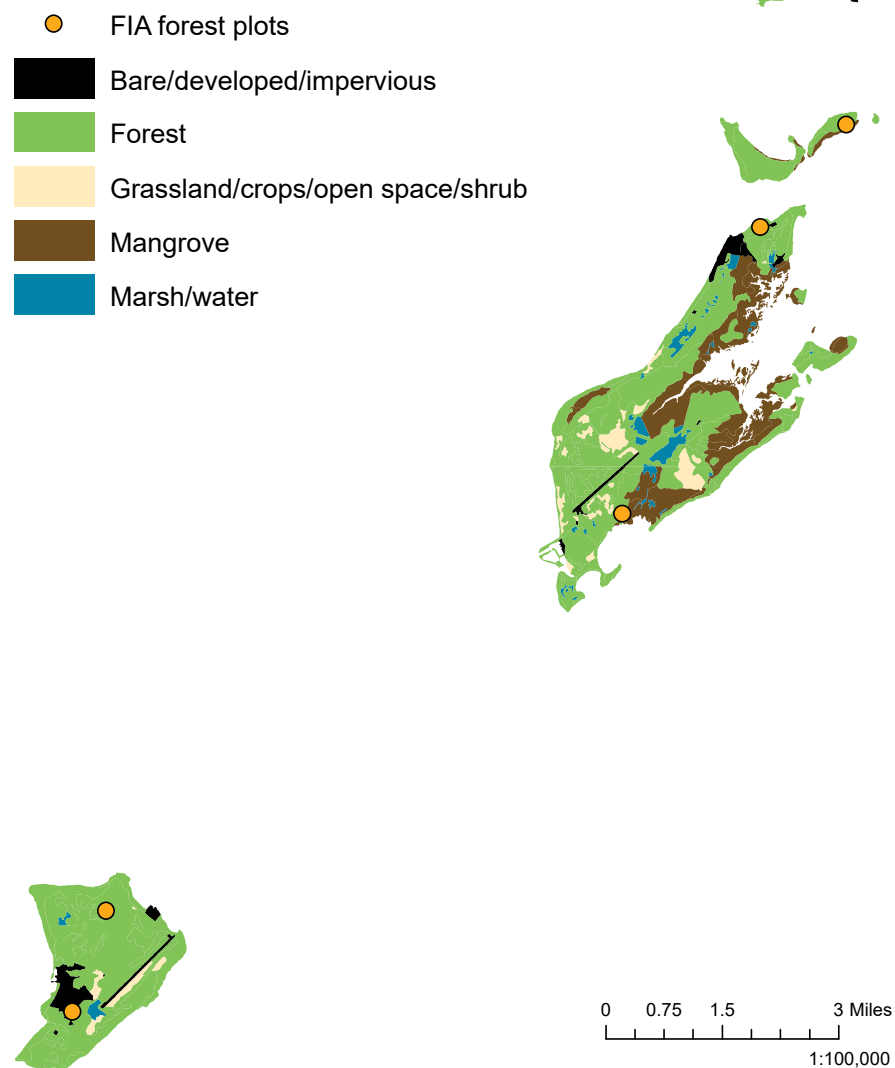


Figure 4—Republic of Palau, Peleliu and Angaur vegetation cover (1976) (Cole et. al 1987) and USDA Forest Service Forest Inventory and Analysis (FIA) forest plots; plot locations are approximate.

Babeldaob is by far the largest island in Palau and the second largest island in Micronesia. Its rolling hilly terrain contains the highest point in the country at about 790 feet above sea level. It has several important watersheds that contain the largest freshwater lake, the longest river, and the largest estuary in Micronesia. Freshwater resources, such as perennial freshwater streams, freshwater marshes, ponds/lakes, and swamp forest, are mostly lacking on the other islands of Palau, and the commercial and residential center in Koror relies on water piped from a reservoir in southern Babeldaob. Overall, 71 percent of the land in

Palau is public and under the jurisdiction of one of its 16 states; 29 percent of the land in Palau is privately owned (Republic of Palau 2010).

Palau has a tropical climate with hot and humid conditions throughout the year. The average daily maximum and minimum temperatures (88.2 and 76.5 °F, respectively) per month vary annually by <2 °F (fig. 5) (NCEI 2019).

Precipitation is much more variable than temperature in Palau; the average monthly rainfall from February to April (8.7 inches) is about 29 percent lower than the annual monthly average (12.2 inches), and the average monthly

rainfall from June to September (15.5 inches) is about 27 percent higher than the annual monthly average. The average monthly rainfall patterns during the sampling interval of this report (2004–2014) appear to differ somewhat from the long-term average from 1953–2003, although the average annual rainfall remained about 147 inches (fig. 6) (NCEI 2019).

Palau lies within the typhoon belt of the Northwest Pacific basin, which is one of the most active regions for typhoons on Earth. Since 1945, Palau has had 68 recorded typhoons, with significant typhoons occurring in 1964 (Typhoons Louise and Opal), 1967 (Typhoon Sally), 1976 (Typhoon Marie), 1990 (Typhoon Mike), 2012 (Typhoon Bopha), and 2013 (Typhoon Haiyan) (CRRF 2014). Typhoons Bopha and Haiyan made significant impacts on forests in Palau, with Bopha affecting mostly Peleliu, Angaur, the Rock Islands, and eastern Babeldaob, and

Haiyan affecting mostly northern Babeldaob and northern atolls.

The most recent soil survey for Palau describes Palau's soil quality and potential effect on forest management, agriculture, and development, and provides a soil map of the soil-vegetation-landscape relationships that have been observed (USDA NRCS 2009). While there are 32 soil types described for Palau, the three broad categories relevant to forests described here are volcanic, limestone, and bottomland soils in mangrove swamp. Generally, volcanic soils, like those found in Babeldaob and Koror proper, are deep and well drained with low nutrient and organic-matter levels and high aluminum levels. Limestone soils on platform islands and the Rock Islands tend to be shallow, well drained, and low in organic matter, while strand forests are on deep and well-drained sandy soils. Soils in mangroves are deep, poorly drained, and high in organic matter, with

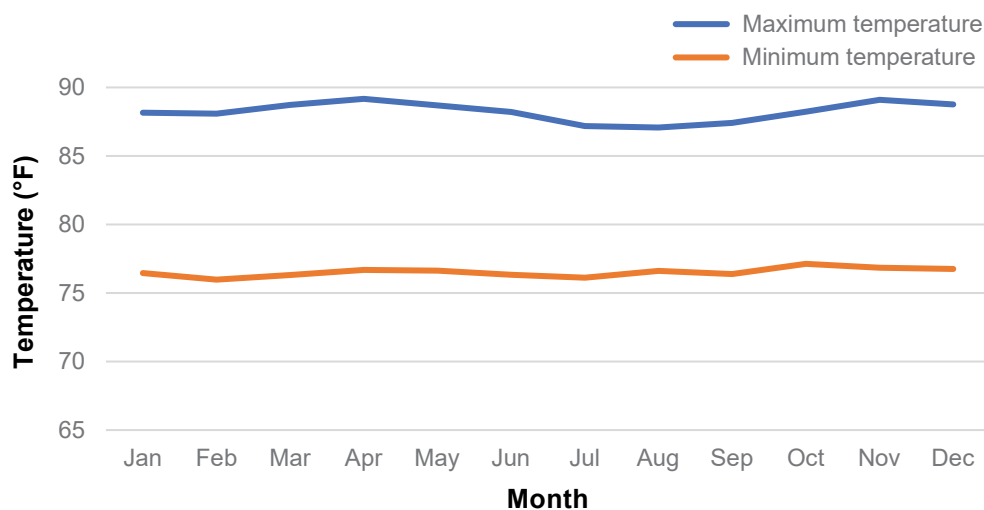


Figure 5—Daily average maximum and minimum temperatures per month from January 2004 to December 2014 at the Republic of Palau, Koror meteorological station (NCEI 2019).

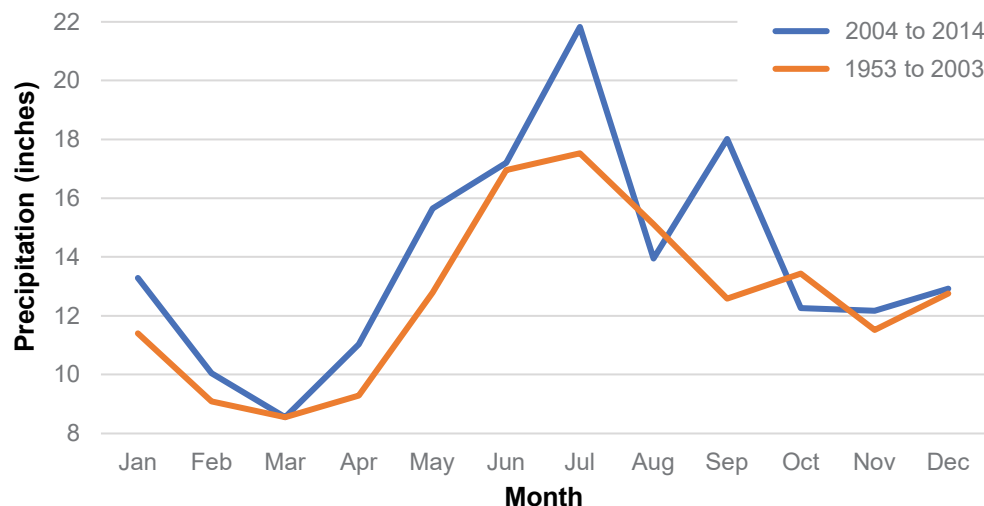


Figure 6—Average monthly precipitation in Republic of Palau from 2004 to 2014 (with 2013 data removed because it was incomplete) and historically (1953 to 2003).

some of the highest soil carbon values measured in the world (Kauffman et al. 2011).

Palau is well known for its spectacular marine habitats and species diversity, but the terrestrial habitats in Palau are less appreciated and studied. However, Palau's forests are known to have high tree species diversity, with one of the highest numbers of endemic plant species per area of any island biodiversity hotspot in the world (Costion and Lorence 2012). Of the about 683 native vascular plant species in Palau, 141, or 20 percent, are endemic (Balick and Kitalong 2020). An additional 654 plant species have been introduced, only a small percentage of which have invaded Palau's intact forests, but at least 86 introduced species and two native species are invasive or potentially invasive in Palau (Balick and Kitalong 2020).

Most forest and nonforest vegetation types that occur in Palau have been described and mapped, including upland volcanic forest, agroforest, plantation forest, limestone forest, atoll forest, Rock Islands forest, *Casuarina* forest, mangrove forest, swamp forest, secondary vegetation, cropland, freshwater marsh, and grassland (including bare areas, fern lands, shrubs, and abandoned agriculture) (Cole et al. 1987). The main forest types and their general characteristics with common species across Micronesia and in Palau are described in *The Vegetation of Tropical Pacific Islands* (Mueller-Dombois and Fosberg 1998). The FIA program adapted its definitions to use as "forest communities" in the region. Field crews inventoried strand or halophytic (salt-tolerant) vegetation (strand forest), lowland tropical rainforest (lowland forest), and mangrove swamp (mangrove) in Palau. Lowland forest was sampled in all the main islands, one mangrove plot was sampled in Peleliu, while the other six were in Babeldaob, and the two strand forest plots were sampled in the Rock Islands.

Forest Inventory and Analysis Program

In 2001, the FIA program increased the plot sampling intensity in the U.S.-Affiliated Pacific Islands and other U.S. territories, including the Republic of Palau, by a factor of three, and plots were sampled every 2,000 rather than every 6,000 acres like they are in U.S. mainland inventories, to better account for the high diversity on a small land mass with a statistically relevant sample.

The FIA plot cluster covered a total area of about 1 acre and was composed of four 24-foot fixed radius subplots,

with three subplots spread out equidistantly around a central subplot, like spokes on a wheel (fig. 7) (USDA FS 2014). Field crews assigned the land area sampled on the plot to condition classes and proportions, including accessible forest land. The forest condition characteristics measured on accessible forest land and estimated for the entire plot footprint included forest disturbances, canopy cover, forest community, and dominant tree species. Crews measured live and dead trees ≥ 5 inches diameter at breast height (DBH) in the subplots, with a cumulative area of about $\frac{1}{5}$ of an acre, or 676 m² (0.07 hectare), and live and dead trees < 5 inches DBH but ≥ 1 inch DBH in the microplots, with a cumulative area of about $\frac{1}{5}$ of an acre, or 53 m² (0.005 hectares). In addition to diameter, crews collected measurements of tree height, tree species, and tree damage from subplots and microplots. Crews collected species cover on each subplot for the four most dominant species (dominant species must meet a 3-percent cover threshold) by different growth habits, which included grasses, shrubs, forbs, and trees. The 2014 Palau forest inventory included additional measurements of invasive plant species, live canopy cover, and tree pathogens unique to this region.

The FIA program uses a statistical method called post-stratification (based on the number of forest pixels in a satellite image used for each measurement cycle) to generate the estimated totals at the jurisdictional level from the plot-level data. This allows for estimates of total numbers or the percentage of trees by species or diameter class; forest area by jurisdiction; or percentage of total forest area by forest community, disturbance, canopy cover, etc. Estimates were calculated based on FIA stratification and estimation procedures (Bechtold and Patterson 2005). Growth, removals, and mortality of trees, and change in forest area over time were calculated using a stratification that links measurements from at least two inventories.

The high species diversity and variability of tropical forests relative to the small land area of Pacific Islands tends to result in high sample error values for FIA estimates in the region. Therefore, for this report, we mostly include results with sample error (SE) values smaller than the mean, because mean estimates with equivalent or larger SE values are unreliable (app. 2). We also use the ratio of SE to the estimate to sort results in order of confidence, with the lowest ratio values indicating the greatest confidence in the estimate.

Estimates for forest area and percentage of forest cover are also available from the USDA Forest Service-led Land Cover Monitoring consortium for the U.S.-Affiliated Pacific Islands (USDA FS 2021), which provides maps that summarize all vegetation cover using high resolution satellite imagery (table 1). Classification of vegetation types in Palau

resulting in the most recent available maps for Babeldaob (fig. 2), Koror/Rock Islands (fig. 3), and Peleliu/Angaur (fig. 4) utilized a variety of classes, making comparison difficult; so we merged vegetation classes to make them comparable across these local regions and the broader Micronesian region overall (Cole et al. 1987, USDA FS

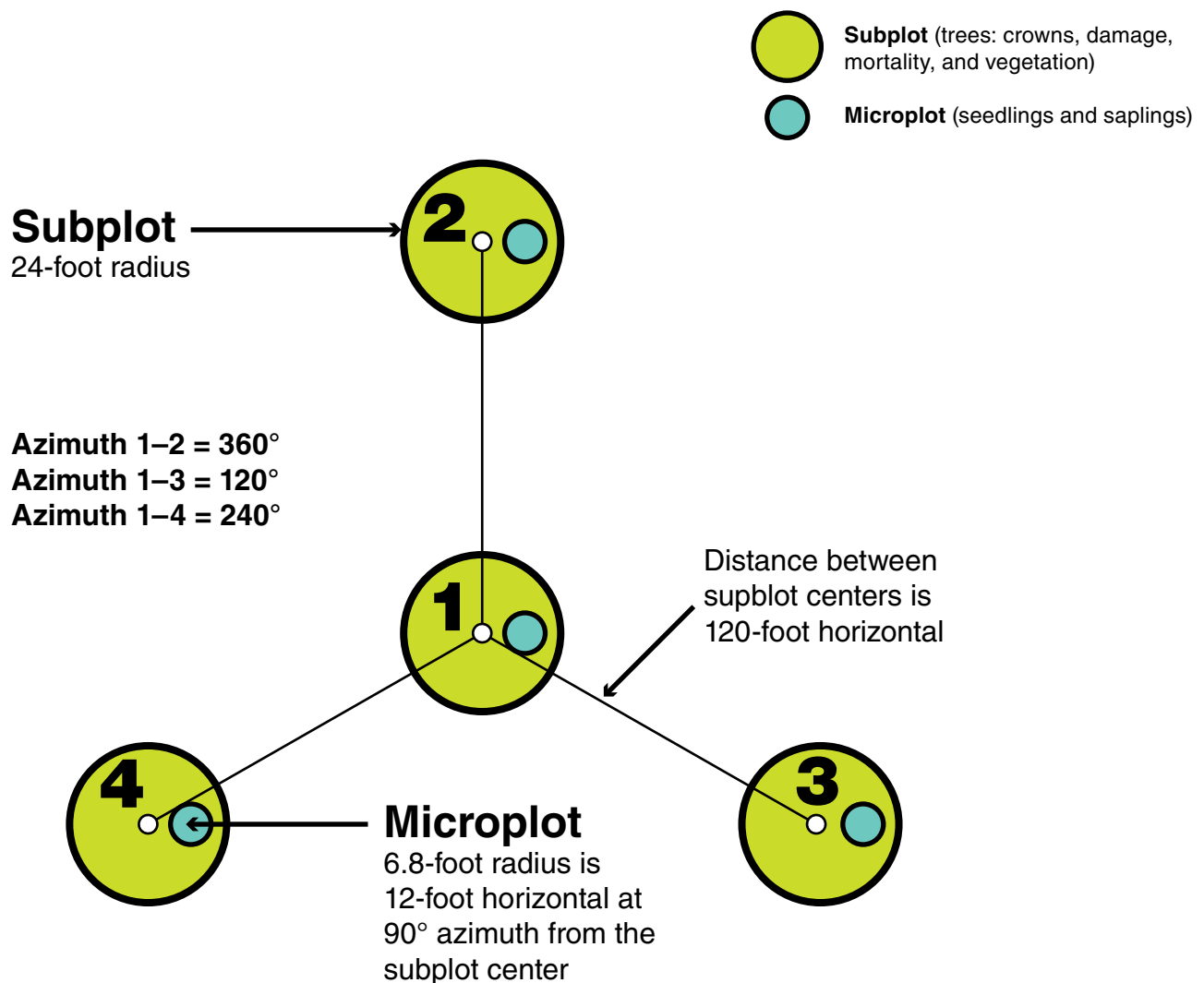


Figure 7—USDA Forest Service Forest Inventory and Analysis plot diagram.

Table 1—Land cover estimates for urban, forest, and mangrove on Republic of Palau main islands, according to most recent available vegetation maps (USDA FS 2021)

Island (time of estimate)	Area	Urban cover	Forest cover	Mangrove cover
	ACRES	PERCENT		
Babeldaob (2014)	90,433	1.0	73.2	10.7
Koror/Rock Islands (2006)	14,479	8.7	84.9	3.8
Peleliu (1976)	4,734	1.9	63.4	24.7
Angaur (1976)	1,983	7.2	85.9	0.0

2021). For classification, we merged all non-mangrove and strand forest types into one forest category equivalent to lowland tropical rainforest; we merged all nonforest vegetation categories into the grassland/crops/open space/shrub category; we merged all urban, built-up, and barren categories into the bare/developed/impervious category; and we merged all freshwater marsh, water, and inland water categories into the marsh/water category. The best available maps for Peleliu and Angaur were based on black-and-white aerial photographs (1976) used to inform a national vegetation survey (Cole et al. 1987) (fig. 4).

Forest Area and Community

According to vegetation maps of Palau (figs. 2–4), about 75 percent of Palau's land area is forested, with coverage of forest, mangrove, and urban land varying by island (table 1). Plots were in three forest communities, including 47 plots in lowland tropical rainforest, 7 plots in mangrove swamp (mangrove), and 2 plots in strand and halophytic vegetation (strand forest). Based on that random sampling, Palau had 102,130 acres of total forest area and 84 percent (SE = 5) of forest area was lowland tropical rainforest, 12 percent (SE = 4) was mangrove, and 4 percent (SE = 3) was strand forest (table 2). The forest area in Palau had a net gain of 4.1 percent (SE = 1.8) between 2003 (Donnegan

et al. 2007) and 2014, and 95.5 percent (SE = 1.7) of total forest area did not change.

Live and Missing Canopy Cover

Multilayered forest vegetation with high percentages of canopy cover maintains understory moisture, regulates temperature, and provides the three-dimensional matrix within which diverse life forms carry out their life cycles (Mueller-Dombois and Fosberg 1998). High canopy cover also protects erodible volcanic soils from intense rains in lowland tropical rainforest. The FIA program defines forests as areas that have ≥ 10 percent live plus missing forest canopy cover (USDA FS 2014). Missing canopy cover was estimated based on canopy cover that existed before disturbance or tree harvesting in the past 30 years. In 2014, nearly two-thirds of total forest area and three-fourths of mangrove had 90 percent live canopy cover or greater (table 3). Overall, mean live canopy cover was 83.6 percent (SE = 2.0). Mean live canopy cover in mangrove was 7.1 percent (SE = 3.2) higher than in lowland forest and 5.6 percent (SE = 3.9) higher than in strand forest. An estimated 2 percent (SE = 1.6) of forest area had 2–4 percent missing canopy cover related to fire disturbance in northern Babeldaob, and 4.8 percent (SE = 2.8) of forest area had 15–25 percent missing canopy cover related to wind disturbance in Angaur.

Table 2—Forest area (mean and sample error [SE]) by forest community in Republic of Palau

Forest community	Forest area	Total forest area	SE
	ACRES	PERCENT	
Lowland tropical rainforest	85,854	84	5
Mangrove swamps	11,980	12	4
Strand or halophytic vegetation	4,296	4	3
Total forest area	102,130	100	

Table 3—Forest area (mean and sample error [SE]) by live canopy cover, forest community, and in total in Republic of Palau

Cover	Lowland area	SE	Mangrove area	SE	Total area	SE
PERCENT						
<60	8.6	3.5	—	—	7.3	3.0
60–70	4.9	3.3	—	—	4.1	2.8
70–80	7.5	3.8	—	—	6.3	3.2
80–90	18.1	5.7	26.4	16.8	20.7	5.5
90–100	60.9	6.6	73.6	16.8	61.6	6.0

Note: strand forest not shown for forest communities (n = 2). — = not observed.

Disturbance

Natural and human disturbances to tropical forests affect canopy cover, structure, and plant species diversity and composition with varied outcomes, depending on the disturbance type, duration and intensity, and the time scale afterward (Mueller-Dombois and Fosberg 1998). Forest disturbances can be either natural or human caused and must meet certain criteria to be recorded as such. They must be at least 1 acre in size and affect at least 25 percent of all the trees, soil surface, or understory vegetation in a stand. If the disturbance is affecting only one tree species, 50 percent of the species must be affected to be recorded (USDA FS 2014). These disturbance evaluation criteria were the same in the 2003 and 2014 inventories.

Weather (wind) was the most prevalent forest disturbance category in 2014, and wind damage affected 11 percent (SE = 4) of total forest area (table 4). Most wind damage was likely caused by Typhoons Bopha and Haiyan, which passed near the main islands of Palau and caused significant damage to Palau forests in 2012 and 2013.

Table 4—Forest area (mean and sample error [SE]) by disturbance type in Republic of Palau

Disturbance type	Forest area	SE
	PERCENT	
Insect	0.0	0.0
Disease	5.3	3.0
Fire	6.8	2.9
Animal	1.8	1.8
Weather	10.9	4.1
Vegetation	3.9	2.5
Unknown	0.0	0.0
Human caused	0.0	0.0
Geological	0.0	0.0
Any disturbance	25.1	5.3
Undisturbed	74.9	5.3



Figure 8—Forest disturbance from fire on Babeldaob Island, Republic of Palau. Photo by Pat Colin.

Fires are primarily anthropogenic in origin on Babeldaob (Dendy et al. 2022a). Since the 2003 measurement, fire affected 7 percent (SE = 3) of total forest area in Palau, with 9 percent (SE = 4) of total forest area affected on Babeldaob.

Tree disease disturbed 5 percent (SE = 3) of forest area, all in mangroves. Vegetation suppression, which refers to vines that cover tree crowns, disturbed 4 percent (SE = 2) of forest area. There was evidence of animal disturbance, likely from pigs (see “Pig damage” below). No human disturbance or silvicultural treatments were observed.

Disturbed forest area increased dramatically between inventories. In 2003, 1 percent (SE = 1) of total forest area was disturbed (Donnegan et al. 2007), whereas 25 percent

(SE = 5) of total forest area was disturbed in 2014. Much of the increase could be attributed either directly or indirectly to typhoon damages and disturbance in 2012 and 2013. The construction of a two-lane highway around the perimeter of Babeldaob from 2003 to 2007 could have also contributed to an increase in disturbance, including fire disturbance, because of increased access to much of the island.

Pig Damage

Evidence of feral pig damage was recorded and estimated at the subplot level by percentage of subplot area damaged. Three percent of subplots measured in Palau had some evidence of pig damage, and pigs damaged an estimated 0.2 percent (SE = 0.1) of total forest area in Palau.



Figure 9—Botanical nursery worker, Olewachel Demei, from Republic of Palau Division of Forestry, Bureau of Agriculture, Ministry of Natural Resources, Environment and Tourism, assesses the forest condition on a USDA Forest Service Forest Inventory and Analysis plot. Photo by Else Demeulenaere.

Trees

Tree Abundance, Dominance, and Species Composition

We used Palauan common species names compiled by Belau National Museum (Balick and Kitalong 2020) for the 2014 inventory, which differ from most common names currently recorded in the USDA PLANTS database. Species Palauan common names are noted parenthetically following their scientific names throughout this report. Appendix 1 provides a list of scientific names and authorities and Palauan common names for plants found during the 2014 forest inventory in Palau.

The most common tree species inventoried in Palau was the palm tree *Pinanga insignis* (ebouch), with three times the abundance of the next two most common species, *Pandanus aimiriikensis* (chertochet) and *Eugenia reinwardtiana* (kesiil) (table 5). *P. insignis* also had the highest

relative dominance, composing 9 percent of total forest basal area (table 6). *Camposperma brevipedolata* (kalel a charm) and *Maranthes corymbosa* (bkau) also composed 6 to 7 percent of total basal area and together dominated a quarter of Palau's total forest acreage (table 7). *P. insignis* tends to dominate the subcanopy (mean height 31.2 feet [SE = 1.3]) while *M. corymbosa* and *C. brevipedolata* are large dominant canopy trees of lowland rainforest on volcanic substrate (mean height 52.6 feet [SE = 5.9] and 46.6 feet [SE = 6.4], respectively). *C. brevipedolata* is perhaps the most iconic Micronesian rainforest tree and grows quickly to large sizes, while providing food for wildlife in a wide range of habitats, including savanna, marsh, lowland tropical rainforest, and swamp forest.

Horsfieldia amklaal (chemeklachel) tends to grow with a small subset of tree species that prefer or can survive in swampy areas and was the largest tree species inventoried

Table 5—Twenty most abundant tree species ≥ 1 inch diameter at breast height (mean and sample error [SE]) in Republic of Palau

Scientific name	Palauan common name	Status	All trees	SE
PERCENT				
<i>Pinanga insignis</i>	Chebouch	N	13.3	2.7
<i>Pandanus aimiriikensis</i>	Chertochet	P	4.1	1.1
<i>Eugenia reinwardtiana</i>	Kesiil	N	4.0	1.2
<i>Ceriops tagal</i>	Biut	N	3.5	3.2
<i>Horsfieldia palauensis</i>	Chersachel	P	3.2	0.7
<i>Rhizophora apiculata</i>	Bngaol	N	2.8	1.7
<i>Astronidium palauense</i>	Meskui	P	2.7	1.1
<i>Bruguiera gymnorhiza</i>	Kodenges	N	2.7	1.7
<i>Eugenia palauensis</i>	Orenged	P	2.6	0.7
<i>Glochidion ramiflorum</i>	Ngolm	U	2.5	0.8
<i>Semecarpus venenosus</i>	Tonget	M	2.4	0.5
<i>Barringtonia racemosa</i>	Koranges	N	2.3	1.7
<i>Rinorea carolinensis</i>	N/A	N	2.0	1.1
<i>Osmoxylon oliveri</i>	Kesiamel	P	1.9	1.2
<i>Parinari laurina</i>	Cheritem	N	1.7	0.8
<i>Rhizophora mucronata</i>	Tebechel	N	1.6	1.3
<i>Pouteria calcarea</i>	Chelangel	P	1.6	0.8
<i>Rhus taitensis</i>	Cheues	N	1.4	0.6
<i>Pouteria obovata</i>	Chelangel	N	1.4	0.5
<i>Timonius mollis</i>	N/A	P	1.3	0.8

Note: N = native, P = endemic to Palau, U = unresolved, M = endemic to Micronesia. Status from Balick and Kitalong 2020.

in 2014. *Canarium vulgare* (mesecheues) was the only dominant tree species recorded exclusively in the Rock Islands and *Pouteria calcarea* (chelangel) was one of several dominant species there and on Angaur. Three mangrove species, *Rhizophora apiculata* (bngaol), *Bruguiera gymnorhiza*¹ (kodenges), and *Rhizophora mucronata* (tebechel), were among the most abundant tree species. These three species and *Sonneratia alba* (urur) were among the most dominant by size (table 6). *B. gymnorhiza*, *R. apiculata*, and

S. alba were among the most dominant by area, despite the small relative acreage of mangroves. This is due to the low overall tree and plant diversity in mangroves, which are constrained by harsh anaerobic and reducing sediments, tidal inundation, flood frequency, and salinity levels.

For each forest condition found on a plot, the three dominant tree species with the largest total canopy cover were recorded. Of the 56 forest plots and 63 conditions measured in Palau, there were 33 dominant tree species recorded, 12 of which had reliable estimates of forest area coverage (table 7). The high number of dominant species compared to the number of measured plots is an indication of the high tree diversity in Palau forests.

¹Species are listed as they appear in the Pacific Islands Public Access Database (October 2021), except for *Bruguiera gymnorhiza* L. Lam. (kodenges), which is listed as *sexangula* in the database. *B. sexangula* occurs across Southeast Asia and is invasive in Hawaii. It is almost indistinguishable from *B. gymnorhiza*, which has a broader distribution from Eastern Africa across Asia and occurs across Micronesia (Allen and Duke 2006).

Table 6—Twenty most dominant tree species by percentage of total basal area (square feet per acre) (mean and sample error [SE]) of live trees ≥1 inch diameter at breast height in Republic of Palau

Scientific name	Palauan common name	Status	Total basal area	SE
			PERCENT	
<i>Pinanga insignis</i>	Chebouch	N	8.6	1.6
<i>Camptosperma brevipetiolata</i>	Kalel a charm	N	6.8	1.8
<i>Maranthes corymbosa</i>	Bkau	N	6.4	1.7
<i>Horsfieldia amklaal</i>	Chemeklachel	N	4.0	2.0
<i>Canarium vulgare</i>	Mesecheues	I	3.5	1.4
<i>Gmelina palawensis</i>	Blacheos	P	2.8	0.7
<i>Sonneratia alba</i>	Urur	N	2.8	2.8
<i>Rhizophora mucronata</i>	Tebechel	N	2.7	2.0
<i>Horsfieldia palauensis</i>	Chersachel	P	2.7	0.5
<i>Rhus taitensis</i>	Cheues	N	2.1	0.5
<i>Manilkara udoido</i>	Udeuid	P	2.1	1.2
<i>Guettarda speciosa</i>	Blau	N	2.0	0.9
<i>Eugenia reinwardtiana</i>	Kesiil	N	2.0	0.7
<i>Rhizophora apiculata</i>	Bngaol	N	1.8	1.2
<i>Semecarpus venenosa</i>	Tonget	M	1.8	0.4
<i>Eugenia palauensis</i>	Orenged	P	1.7	0.6
<i>Pouteria calcarea</i>	Chelangel	P	1.7	0.7
<i>Bruguiera gymnorhiza</i>	Kodenges	N	1.6	0.7
<i>Ficus microcarpa</i>	Lulk	N	1.6	1.0
<i>Vitex cofassus</i>	Bars, beokel	N	1.5	1.5

Note: N = Native, I = introduced, P = endemic to Palau, M = endemic to Micronesia.
Status from Balick and Kitalong 2020.

Table 7—Twelve most dominant tree species by total forest area (with sample error [SE]) in Republic of Palau

Scientific name	Palauan common name	Status	Total forest area	SE
			PERCENT	
<i>Camposperma brevipetiolata</i>	Kalel a charm	N	14.9	4.5
<i>Maranthes corymbosa</i>	Bkau	N	9.9	4.0
<i>Pinanga insignis</i>	Chebouch	N	5.3	3.1
<i>Parinari laurina</i>	Cheritem	N	5.2	3.1
<i>Rhus taitensis</i>	Cheues	N	5.0	2.6
<i>Bruguiera gymnorhiza</i>	Kodenges	N	4.7	2.7
<i>Pandanus tectorius</i>	Ongorraked	N	4.7	2.7
<i>Cocos nucifera</i>	Lius	N	4.1	2.8
<i>Rhizophora apiculata</i>	Bngaol	N	3.8	2.4
<i>Canarium vulgare</i>	Mesecheues	I	3.6	2.5
<i>Garcinia matsudai</i>	Tilol	M	3.4	2.5
<i>Manilkara udoido</i>	Udeuid	M	3.1	2.3

Note: Dominant trees were selected based on aerial cover. N=native, I=introduced, M=endemic to Micronesia. Status from Balick and Kitalong 2020.



Figure 10—USDA Forest Service Forest Inventory and Analysis plot in a mangrove swamp on Babeldaob Island, Republic of Palau. Photo by Seth Ayotte.

Field crews inventoried a total of 125 tree species, 85 of which (68 percent of species inventoried) had reliable abundance estimates for all diameter classes (table 8). About 43 percent of species inventoried only had trees that were measured at <10 inches DBH, and 16 percent of species inventoried were only measured as saplings <5 inches DBH. The high proportions of species occurring only as saplings or small-diameter trees describe lowland forest with a substantial component of small-tree and shrub diversity. Twenty-nine percent (SE = 3) of all inventoried tree species in Palau were endemic to Palau, and 37 percent (SE = 3) were endemic to Palau or Micronesia.

On average, there were 12.6 tree species per plot (SE = 5.9) across all forest communities, and tree species diversity per plot was 2.5 times higher in lowland forest than in mangroves and 56 percent higher than in strand forest (table 9). There were about four more tree species per plot on limestone compared to volcanic substrates in lowland tropical rainforest. About 30 percent of plots (17 of 56) were measured in partial forest, and the mean species richness in 100 percent forest plots was 13.5 in lowland forest (n = 39, SE = 5.7), and 6 (n = 3, SE = 5.2) in mangrove.

Table 8—Number of live trees on forest land (mean and sample error [SE]) by species and diameter class in Republic of Palau

Scientific name (Palauan common name)	1–4.9 inch diameter class		5–10 inch diameter class		>10 inch diameter class		All diameter classes	
	Total	SE	Total	SE	Total	SE	Total	SE
NUMBER OF TREES								
<i>Pinanga insignis</i> (chebouch)	10,872,244	2,133,871	1,827,644	363,057	—	—	12,699,888	2,414,536
<i>Pandanus aimiriikensis</i> (chertochet)	3,949,384	1,076,119	—	—	—	—	3,949,384	1,076,119
<i>Eugenia reinwardtiana</i> (kesiil)	3,144,112	998,516	650,648	301,213	44,456	21,091	3,839,215	1,216,654
<i>Ceriops tagal</i> (biut)	3,345,965	3,103,895	—	—	—	—	3,345,965	3,103,895
<i>Horsfieldia palauensis</i> (chersachel)	2,013,180	585,691	919,359	167,733	110,042	47,592	3,042,581	689,460
<i>Rhizophora apiculata</i> (bngaol)	2,091,228	1,381,959	489,012	322,536	66,683	56,878	2,646,924	1,656,943
<i>Astronidium palauense</i> (mesekui)	2,133,620	1,017,292	391,693	115,633	32,245	24,739	2,557,558	1,075,543
<i>Bruguiera gymnorhiza</i> (kodenges)	2,230,643	1,602,381	188,937	122,342	133,367	61,161	2,552,947	1,659,069
<i>Eugenia palauensis</i> (orenged)	2,052,204	604,473	330,126	115,712	120,607	60,503	2,502,938	674,458
<i>Glochidion ramiflorum</i> (ngolm)	2,228,425	802,191	94,036	31,036	53,375	32,351	2,375,836	809,318
<i>Semecarpus venenosa</i> (tonget)	1,802,375	491,641	400,289	91,087	55,021	36,808	2,257,684	518,131
<i>Barringtonia racemosa</i> (koranges)	2,036,595	1,481,842	150,658	99,488	21,131	22,038	2,208,384	1,587,820
<i>Rinorea carolinensis</i>	1,812,398	1,099,926	44,456	26,602	11,114	11,242	1,867,967	1,127,900
<i>Osmoxylon oliveri</i> (kesiamel)	1,757,764	1,125,523	75,055	44,802	—	—	1,832,819	1,154,414
<i>Parinari laurina</i> (cheritem)	1,215,713	622,451	337,401	176,396	85,620	35,926	1,638,734	722,047

Table 8 (continued)—Number of live trees on forest land (mean and sample error [SE]) by species and diameter class in Republic of Palau

Scientific name (Palauan common name)	1–4.9 inch diameter class		5–10 inch diameter class		>10 inch diameter class		All diameter classes	
	Total	SE	Total	SE	Total	SE	Total	SE
	NUMBER OF TREES							
<i>Rhizophora mucronata</i> (tebechel)	418,246	310,236	1,044,708	911,250	88,911	55,620	1,551,865	1,223,203
<i>Pouteria calcarea</i> (chelangel)	1,104,154	702,279	239,754	111,946	150,979	58,993	1,494,887	759,559
<i>Rhus taitensis</i> (cheues)	842,078	582,192	330,635	82,853	202,432	56,256	1,375,145	601,748
<i>Pouteria obovata</i> (chelangel)	960,297	447,485	324,641	112,472	43,359	21,741	1,328,297	489,843
<i>Timonius mollis</i>	1,285,959	735,247	—	—	—	—	1,285,959	735,247
<i>Camposperma brevipetiolata</i> (kalel a charm)	447,247	249,583	246,159	117,849	582,418	158,072	1,275,824	304,966
<i>Timonius subauritus</i> (blauelked)	1,146,544	723,799	25,887	17,256	—	—	1,172,431	735,533
<i>Guettarda speciosa</i> (blau)	697,076	455,637	199,502	111,626	233,392	126,646	1,129,970	577,481
<i>Aidia cochinchinensis</i> (kerumes)	1,109,738	592,203	11,114	11,242	—	—	1,120,852	594,660
<i>Gmelina palawensis</i> (blacheos)	455,051	255,577	362,191	99,912	296,236	81,770	1,113,478	309,315
<i>Alphitonia carolinensis</i> (chelebiob)	736,103	652,305	259,467	112,331	97,283	44,202	1,092,853	662,916
<i>Garcinia rumiyo</i> (tilol)	820,882	479,355	199,502	112,797	33,342	24,731	1,053,725	549,943
<i>Macaranga carolinensis</i> (bedel)	973,688	518,213	35,904	20,036	—	—	1,009,592	519,453
<i>Timonius timon</i> (liberal)	920,129	815,382	59,093	40,254	—	—	979,221	853,565
<i>Manilkara udoido</i> (udeuid)	402,636	308,621	435,780	284,822	138,996	76,591	977,412	506,484
<i>Canarium vulgare</i> (mesecheues)	418,246	234,274	244,506	120,992	299,803	134,703	962,555	427,660
<i>Hibiscus tiliaceus</i> (chermall)	789,662	600,785	105,654	70,601	10,565	11,019	905,882	653,451
<i>Symplocos racemosa</i> (chebtui)	526,442	321,133	338,225	120,117	32,245	18,879	896,912	354,858
<i>Diospyros ferrea</i>	881,102	389,198	—	—	—	—	881,102	389,198
<i>Cleistanthus carolinianus</i>	836,491	620,471	44,456	31,153	—	—	880,947	639,758
<i>Xylocarpus granatum</i> (meduulokebong)	697,076	498,966	77,797	55,118	88,911	79,043	863,785	606,986
<i>Cyathea nigricans</i> (cheluu)	410,441	313,660	407,338	132,963	21,131	22,038	838,910	344,415
<i>Pandanus tectorius</i> (ongorraked)	507,467	355,332	323,773	166,781	—	—	831,239	485,801
<i>Morinda citrifolia</i> (ngel)	733,882	316,731	87,814	33,159	—	—	821,696	314,351
<i>Kayea pacifica</i> (ketenguit)	741,687	423,456	11,114	11,242	10,565	11,019	763,366	430,871
<i>Flacourtia rukam</i> (chemechong)	594,467	289,162	131,173	37,413	10,565	11,019	736,205	292,938

Table 8 (continued)—Number of live trees on forest land (mean and sample error [SE]) by species and diameter class in Republic of Palau

Scientific name (Palauan common name)	1–4.9 inch diameter class		5–10 inch diameter class		>10 inch diameter class		All diameter classes	
	Total	SE	Total	SE	Total	SE	Total	SE
	NUMBER OF TREES							
<i>Maranthes corymbosa</i> (bkau)	131,610	137,260	169,639	61,466	413,372	98,120	714,621	240,839
<i>Dracaena multiflora</i> (orredakl)	455,051	255,577	156,511	54,233	10,565	11,019	622,128	278,588
<i>Morinda pedunculata</i> (kesengelngel)	557,661	333,705	53,924	28,708	—	—	611,585	338,328
<i>Premna obtusifolia</i> (chosm)	462,856	325,785	129,527	54,068	—	—	592,383	338,210
<i>Trichospermum ledermannii</i> (chelsau)	315,636	213,153	209,659	128,358	21,679	15,741	546,974	316,279
<i>Buchanania engleriana</i> (omail)	402,636	235,761	116,264	41,035	10,565	11,019	529,465	235,028
<i>Cerbera manghas</i> (chemeridech)	271,026	196,789	128,979	48,336	53,924	32,970	453,928	202,581
Tree unknown	323,441	215,591	48,115	36,176	55,570	36,323	427,125	248,054
<i>Horsfieldia amklaal</i> (chemeklachel)	139,415	141,016	100,025	74,194	186,742	92,627	426,183	250,368
<i>Sonneratia alba</i> (urur)	278,830	282,032	22,228	22,483	122,253	123,657	423,311	428,172
<i>Meryta senftiana</i> (omechidel)	418,246	234,274	—	—	—	—	418,246	234,274
<i>Glochidion</i> spp.	278,830	282,032	100,025	56,028	33,342	24,731	412,197	309,081
<i>Polyscias macgillivrayi</i> (bngai)	402,636	308,621	—	—	—	—	402,636	308,621
<i>Syzygium samarangense</i> (rebotel)	184,026	163,076	90,789	48,365	118,185	67,910	393,000	256,380
<i>Fagraea ksid</i> (ksid)	184,026	163,076	102,039	53,351	95,133	36,884	381,197	214,704
<i>Pandanus dubius</i> (bekuu)	278,830	282,032	100,025	90,185	—	—	378,856	371,685
<i>Pisonia grandis</i> (mesbesibech, chemoi)	315,636	213,153	14,773	13,091	44,320	39,274	374,729	255,452
<i>Aglaia mariannensis</i> (mesecheues)	278,830	195,398	88,911	55,620	—	—	367,742	198,103
<i>Mammea odorata</i> (ongolbesachel, kodebisech, safaireng)	139,415	141,016	77,797	47,428	133,367	86,143	350,580	187,707
<i>Calophyllum pelewense</i> (chesemolech)	278,830	282,032	11,114	11,242	44,456	31,153	334,400	315,658
<i>Cerbera floribunda</i> (chemeridech)	131,610	137,260	151,755	57,561	43,907	21,684	327,273	197,593
<i>Buchanania palawensis</i> (omail)	263,221	274,521	42,810	34,916	—	—	306,031	307,783
<i>Badusa palauensis</i> (ralm)	139,415	141,016	55,021	23,796	99,477	69,225	293,913	169,643
<i>Vitex cofassus</i> (beokl, bars)	278,830	195,398	—	—	—	—	278,830	195,398
<i>Calophyllum inophyllum</i> (btaches)	278,830	282,032	—	—	—	—	278,830	282,032
<i>Elaeocarpus joga</i> (dekemerir)	131,610	137,260	40,660	20,928	88,911	89,932	261,182	171,430

Table 8 (continued)—Number of live trees on forest land (mean and sample error [SE]) by species and diameter class in Republic of Palau

Scientific name (Palauan common name)	1–4.9 inch diameter class		5–10 inch diameter class		>10 inch diameter class		All diameter classes	
	Total	SE	Total	SE	Total	SE	Total	SE
NUMBER OF TREES								
<i>Swietenia mahagoni</i> (mahongani)	—	—	151,619	59,281	90,376	34,421	241,995	81,904
<i>Canarium hirsutum</i> (mesecheues)	—	—	152,852	53,060	87,814	49,130	240,666	78,218
<i>Terminalia catappa</i> (miich)	131,610	137,260	52,827	38,752	53,924	32,970	238,361	173,284
<i>Cocos nucifera</i> (lius)	131,610	137,260	43,359	21,741	53,375	28,124	228,345	149,887
<i>Casearia cauliflora</i>	184,026	163,076	—	—	42,262	34,290	226,287	166,642
<i>Colona scabra</i> (chuchab, cheriut)	—	—	36,452	20,474	175,861	87,163	212,313	103,843
<i>Intsia bijuga</i> (dort)	184,026	163,076	22,228	22,483	—	—	206,254	164,619
<i>Hernandia sonora</i> (doko)	131,610	137,260	42,262	44,076	31,696	33,057	205,568	214,393
<i>Allophylus timorensis</i> (chebeludes)	—	—	122,253	76,343	66,683	40,719	188,937	113,423
<i>Myrsine palauensis</i> (kulsill)	184,026	163,076	—	—	—	—	184,026	163,076
<i>Anacolosa glochidiiformis</i> (churalanguis)	184,026	163,076	—	—	—	—	184,026	163,076
<i>Cinnamomum carolinense</i>	139,415	141,016	35,904	20,036	—	—	175,319	142,432
<i>Calophyllum soulattri</i> (olebtaches, btacheschol)	131,610	137,260	21,679	15,741	—	—	153,290	148,705
<i>Medusanthra carolinensis</i>	139,415	141,016	11,114	11,242	—	—	150,529	152,258
<i>Polyscias</i> spp.	139,415	141,016	—	—	—	—	139,415	141,016
<i>Drypetes nitida</i> (keuert)	139,415	141,016	—	—	—	—	139,415	141,016
<i>Adenanthra pavonina</i> (telengtungdallel)	139,415	141,016	—	—	—	—	139,415	141,016
<i>Ficus</i> spp.	—	—	118,826	46,964	14,773	13,091	133,599	58,355
<i>Adenanthra pavonina</i> (telengtungdallel)	131,610	137,260	—	—	—	—	131,610	137,260
<i>Ficus</i> spp.	131,610	137,260	—	—	—	—	131,610	137,260
<i>Psychotria kaduana</i>	131,610	137,260	—	—	—	—	131,610	137,260
<i>Goniiothalamus carolinensis</i> (chelideu)	131,610	137,260	—	—	—	—	131,610	137,260
<i>Phaleria nissidai</i> (ongael, delalakar)	131,610	137,260	—	—	—	—	131,610	137,260
<i>Myrsine</i> spp.	131,610	137,260	—	—	—	—	131,610	137,260
<i>Mallotus tiliifolius</i> (dachelcharm)	131,610	137,260	—	—	—	—	131,610	137,260
<i>Areca catechu</i> (buuch)	—	—	95,089	99,171	—	—	95,089	99,171
<i>Morinda latibractea</i> (kesengelngel)	—	—	84,523	88,152	—	—	84,523	88,152
<i>Ficus microcarpa</i> (lulk)	—	—	11,114	11,242	68,697	38,817	79,811	40,161
<i>Stemonurus ammui</i> (ngmui)	—	—	22,228	22,483	44,456	44,966	66,683	67,449
<i>Inocarpus fagifer</i> (keam)	—	—	44,456	44,966	11,114	11,242	55,570	56,208

Table 8 (continued)—Number of live trees on forest land (mean and sample error [SE]) by species and diameter class in Republic of Palau

Scientific name (Palauan common name)	1–4.9 inch diameter class		5–10 inch diameter class		>10 inch diameter class		All diameter classes	
	Total	SE	Total	SE	Total	SE	Total	SE
NUMBER OF TREES								
<i>Artocarpus mariannensis</i> (chebiei, meduuliou)	—	—	—	—	50,677	34,223	50,677	34,223
<i>Myristica hypargyrea</i>	—	—	22,228	22,483	22,228	22,483	44,456	44,966
<i>Pterocarpus indicus</i> (las)	—	—	31,696	24,115	10,565	11,019	42,262	30,335
<i>Ormosia calavensis</i> (chedebsungel, chedebsungelked)	—	—	10,565	11,019	31,696	24,115	42,262	25,780
<i>Dolichandrone spathacea</i> (rriu)	—	—	33,342	33,725	—	—	33,342	33,725
<i>Pandanus kanehirae</i> (buuk)	—	—	33,342	33,725	—	—	33,342	33,725
<i>Girardinia celastroides</i> (cheliu)	—	—	32,245	24,739	—	—	32,245	24,739
<i>Tristropsis obtusangula</i>	—	—	31,696	33,057	—	—	31,696	33,057
<i>Casuarina equisetifolia</i> (ngas)	—	—	14,773	13,091	14,773	13,091	29,546	17,652
<i>Neisosperma oppositifolia</i> (uach)	—	—	14,773	13,091	14,773	13,091	29,546	26,183
<i>Pangium edule</i> (riamel)	—	—	11,114	11,242	11,114	11,242	22,228	22,483
<i>Lumnitzera littorea</i> (mekekad)	—	—	11,114	11,242	11,114	11,242	22,228	22,483
<i>Neuburgia celebica</i> (ralm)	—	—	10,565	11,019	11,114	11,242	21,679	15,741
<i>Nephelium lappaceum</i> (rambotang)	—	—	10,565	11,019	11,114	11,242	21,679	15,741
<i>Barringtonia asiatica</i> (bduul)	—	—	14,773	13,091	—	—	14,773	13,091
<i>Ficus tinctoria</i> (oseked)	—	—	14,773	13,091	—	—	14,773	13,091
<i>Pleomele hawaiiensis</i>	—	—	14,773	13,091	—	—	14,773	13,091
<i>Dodonaea viscosa</i> (mesechelangel)	—	—	—	—	14,773	13,091	14,773	13,091
<i>Eugenia javanica</i>	—	—	14,773	13,091	—	—	14,773	13,091
<i>Cynometra ramiflora</i> (ketenguit)	—	—	—	—	11,114	11,242	11,114	11,242
<i>Fagraea berteriana</i> (chelilai)	—	—	—	—	11,114	11,242	11,114	11,242
<i>Ficus carica</i>	—	—	—	—	11,114	11,242	11,114	11,242
<i>Millettia pinnata</i> (kisaks)	—	—	11,114	11,242	—	—	11,114	11,242
<i>Shirakiopsis indica</i>	—	—	11,114	11,242	—	—	11,114	11,242
<i>Psychotria</i> spp.	—	—	10,565	11,019	—	—	10,565	11,019
<i>Glochidion kanehirae</i> (kesengelngolm)	—	—	10,565	11,019	—	—	10,565	11,019
<i>Finschia chloroxantha</i>	—	—	10,565	11,019	—	—	10,565	11,019
<i>Heterospatha elata</i> (demailei, beokl)	—	—	10,565	11,019	—	—	10,565	11,019

Table 9—Number of forest plots, and average number of tree and dominant vascular plant species per plot with sample error (SE) by forest community in Republic of Palau

Forest community	Number of plots	Number of tree species	SE	Number of dominant plant species	SE
Strand forest	2	9	0	11	2
Mangrove swamps	7	4	1	4	1
Lowland rainforest	47	14	1	16	1

Note: — = not observed.



Figure 11—Invasive plant eradication coordinator assistant, Dino Mesubed, from Republic of Palau Division of Forestry, Bureau of Agriculture, Ministry of Natural Resources, Environment and Tourism, measures the diameter of a young sapling in the Lake Ngardok Nature Reserve on Babeldaob Island, Republic of Palau. Photo by Amanda Uowolo.

Diameter and Height

In 2014, the mean diameter of all live trees ≥ 1 -inch DBH was 3.9 inches (SE = 0.1), and the mean tree height was 26.9 feet (SE = 0.9). The quadratic mean diameter was 5.3 inches. Almost 9 out of 10 trees were < 7 inches DBH (table 10). The size distribution for diameter was heavily weighted toward the smallest diameter class (1-to-3-inch DBH) (fig. 12), and the height distribution was weighted toward the 15-to-24-foot height class (fig. 13). The tallest tree was a *Casuarina equisetifolia* (ngas) (107 feet tall and 26.4 inches DBH). A *Horsfieldia amklaal* (chemeklachel) tree had the largest diameter (45.4 inches DBH and 104 feet tall).

There were significant differences between diameter classes in lowland forest among Babeldaob, the Rock Islands, and Peleliu/Angaur. Peleliu/Angaur had the

highest percentage of trees in the 1-to-4.9-inch class and the lowest percentage of trees that were ≥ 5 inches DBH. The Rock Islands had the highest percentage of trees with ≥ 10 inches DBH (fig. 14).

Between 2003 and 2014, there were no significant changes in mean tree diameter or percentage of trees by diameter class (fig. 15), but mean tree height increased by 2 feet (SE = 1.1). There were also significant changes in the percentage of trees by diameter class in lowland forest by island group. The percentage of trees in the 1-to-4.9-inch diameter class increased by 4.1 percent (SE = 2.8) in Peleliu/Angaur (fig. 16), and on Babeldaob, the percentage of trees in the 1-to-2.9-inch class decreased by 5.9 percent (SE = 5.0), and the percentage of trees in the 3-to-4.9-inch class increased by 4.2 percent (SE = 3.7). Sample error values are conservative estimates.

Table 10—Live trees by diameter class (mean and sample error [SE]) in Republic of Palau

Diameter class	All trees	SE
INCHES	PERCENT	
1.0–2.9	52.2	3.0
3.0–4.9	25.8	2.1
5.0–6.9	10.3	0.9
7.0–8.9	4.3	0.5
9.0–10.9	2.7	0.3
11.0–12.9	1.7	0.2
13.0–14.9	1.0	0.2
15.0–16.9	0.6	0.1
≥ 17	1.3	0.2

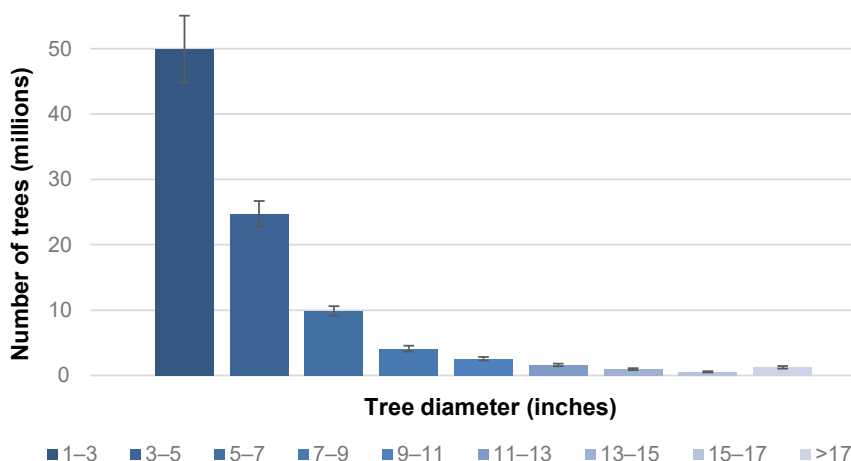


Figure 12—Number of live trees by diameter class on Republic of Palau forest land. Error bars represent 68 percent confidence level.

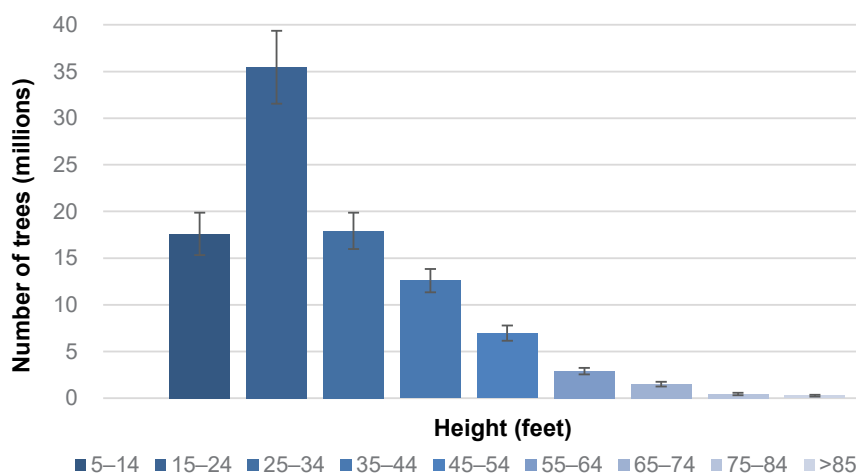


Figure 13—Number of live trees by height class on Republic of Palau forest land. Error bars represent 68 percent confidence level.

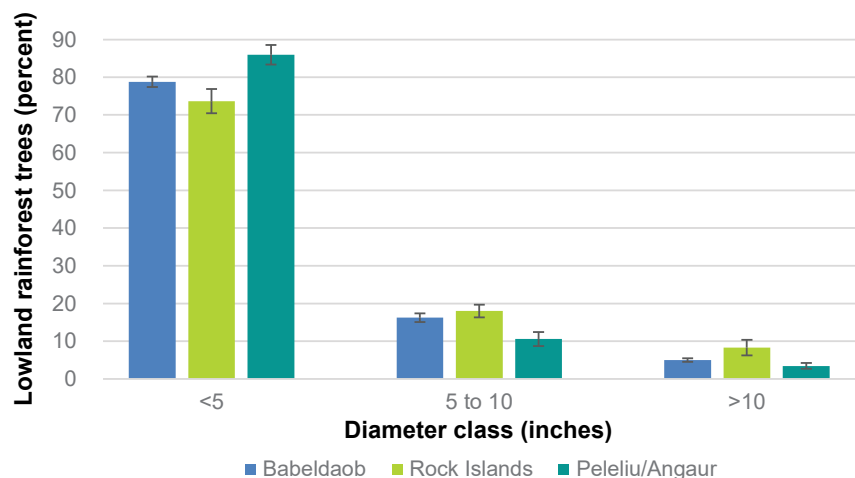


Figure 14—Trees by diameter class (grouping) in lowland rainforest on Babeldaob, Rock Islands, and Peleliu/Angaur, Republic of Palau in 2014. Error bars represent 68 percent confidence level.

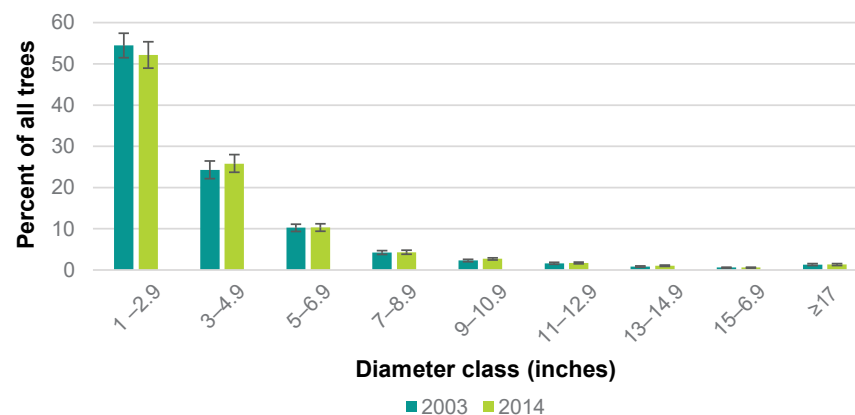


Figure 15—Live trees by diameter class in 2003 and 2014 USDA Forest Service Forest Inventory and Analysis inventories in Republic of Palau. Error bars represent 68 percent confidence level.

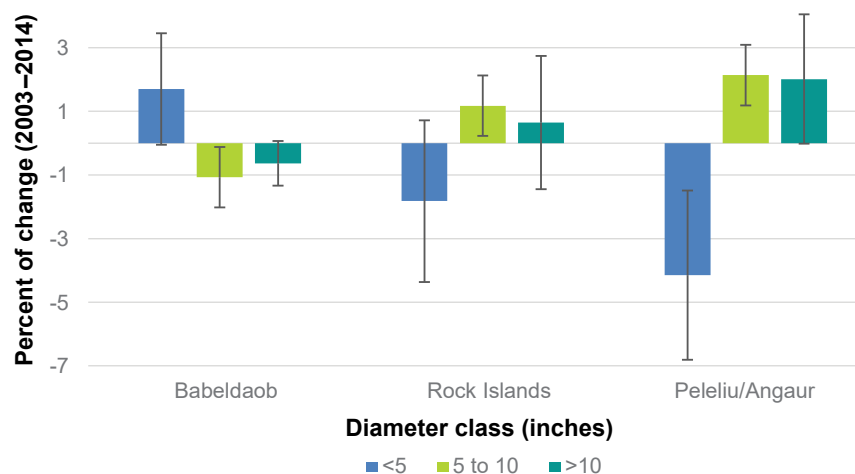


Figure 16—Change in percentage of trees by diameter class (grouping) between 2003 and 2014 in USDA Forest Service Forest Inventory and Analysis inventories in lowland forest on Babeldaob, the Rock Islands, and Peleliu/Angaur in Republic of Palau. Error bars represent 68 percent confidence level. Sample error values are conservative estimates.

Tree Damages

Assessing tree damages can provide insights into the status of many forest health issues and successional patterns. Many damage agents, including insects, disease, weather, vegetation suppression, humans, and animals, can affect the health of each tree. Field crews assessed damages on trees from bottom to top, prioritized them in order of leading to mortality, reduced near-term growth, and the effect on the tree reaching a marketable product, and recorded up to three damage agents per tree. Crews recorded root and butt damages, cankers, and stem decay when any evidence of them was detected. Crews coded other damage agents only if they met a certain presence threshold that would lead to death or reduced growth. Details on this field protocol and the listed thresholds by damage agent can be found in the field instructions for the inventory of the Pacific Islands (USDA FS 2014).

In 2014, 24.8 percent (SE = 2.2) of all live trees ≥ 1 -inch DBH were damaged; the most common damage type was disease, which affected 16.4 percent (SE = 1.7) of trees (table 11). Trees with damage increased by more than 10 percent compared to the 2003 inventory, and it seems possible that Typhoon Haiyan (in 2012) and Typhoon Bopha (2013) contributed to more tree disease, although the construction of a two-lane highway around the perimeter of Babeldaob Island from 2003 to 2007 may have also affected the forest in that way.

There were 12 tree species with damages estimated on more than half of all trees, but results for damage types

other than disease were unreliable, except for weather damage to *Syzygium samarangense* (rebotel) and unknown damage to *Horsfieldia amklaal* (chemeklachel) (table 12). Tree disease estimates were generally more reliable for most species than other damage types.

Pacific Island-Specific Damages (Coconut Rhinoceros Beetle)

A priority damage is a parameter specific to the Pacific Islands inventory that describes a damage that does not meet the national minimum thresholds for recording damage but is of special interest to this region (USDA FS 2014). Of the eight priority damages on the FIA list, only feral pig damage and coconut rhinoceros beetle, *Oryctes rhinoceros* (L.), were recorded in Palau. Pig damage was observed at the subplot level, but no pig damage to trees was observed. *O. rhinoceros* beetles were observed in 40 percent (SE = 22) of coconut trees, *Cocos nucifera* (lius), with an average of about 17 percent of coconut tree crown surface area damaged. Of the eight coconut trees that were observed as dead in 2014, none were killed by insects, and six were killed by weather. An endemic cycad species, *Cycas micro-nesica* (K.D. Hill), occurs in Palau, but was not observed, and an outbreak of invasive cycad scale devastated the cycad population on the U.S. territory of Guam between inventories there.

Epiphyte Loading

Epiphytes are vascular plants that grow on trees or other plants and include orchids, forbs, and vines. Epiphytes are common in tropical forests and often make up a substantial component of total species diversity in lowland or montane tropical rainforest. However, when epiphyte load becomes excessive, it can cause tree damage, mortality, and lack of growth. Epiphyte load was estimated for each tree that was ≥ 1 -inch DBH using a composite score of light (1) or heavy (2) epiphyte loads in three sections of the bottom, middle, and top of each tree. In 2014, about 4 percent of all trees were heavily covered in epiphytes (composite code 6), 10 percent were moderately covered (composite codes 4 and 5), 49 percent were lightly covered (composite codes 1 through 3), and 41 percent had no epiphytes (composite code 0) (fig. 17). The overall percentage of trees with moderate to heavy epiphyte loads decreased slightly, and the percentage with no epiphytes increased slightly compared to the 2003 survey.

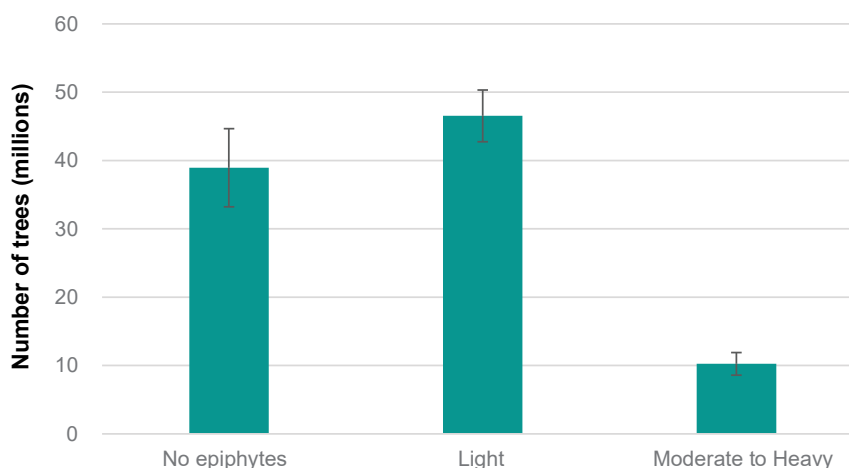
Table 11—Damages to live trees ≥ 1 inch diameter at breast height (mean and sample error [SE]) in Republic of Palau by damage type

Damage type	Total	SE
None	75.2	2.2
Any	24.8	2.2
Disease	16.4	1.7
Unknown	5.0	0.8
Vegetation	4.3	1.1
Weather	2.8	0.9
Physical	0.5	0.3
Fire	0.4	0.4
Insects	0.0	0.0

Table 12—Live trees ≥ 1 inch diameter at breast height (mean and sample error [SE]) in Republic of Palau by species ($n \geq 40$) and damage type

Tree species	Disease		Weather		Vegetation		Unknown		Any damage		No damage	
	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
<i>Pandanus tectorius</i>	66.9	13.9	3.6	3.6	—	—	3.0	2.8	66.9	13.9	33.1	13.9
<i>Maranthes corymbosa</i>	46.8	9.5	—	—	9.2	5.3	22.0	13.1	48.4	9.3	51.6	9.3
<i>Guettarda speciosa</i>	43.4	14.7	4.9	3.3	2.0	1.5	1.0	1.0	47.3	13.9	52.7	13.9
<i>Horsfieldia palauensis</i>	25.2	6.7	0.7	0.5	7.1	5.1	12.1	6.6	43.7	7.7	56.3	7.7
<i>Astronidium palauense</i>	25.6	14.9	—	—	0.9	0.9	22.0	6.9	37.1	12.4	62.9	12.4
<i>Gmelina palawensis</i>	30.3	10.1	3.0	1.5	2.0	1.4	1.9	1.5	33.3	10.2	66.7	10.2
<i>Pouteria obovata</i>	29.2	18.7	—	—	—	—	1.7	1.0	29.2	18.7	70.8	18.7
<i>Buchanania engleriana</i>	26.9	21.8	—	—	—	—	—	—	26.9	21.8	73.1	21.8
<i>Eugenia palauensis</i>	14.3	7.7	0.4	0.4	6.5	5.7	11.4	6.9	26.5	9.8	73.5	9.8
<i>Canarium vulgare</i>	18.1	6.5	3.8	1.9	1.2	1.2	3.8	1.9	22.7	6.6	77.3	6.6
<i>Eugenia reinwardtiana</i>	17.8	6.8	0.3	0.3	0.6	0.6	0.3	0.3	18.4	6.9	81.6	6.9
<i>Rhizophora apiculata</i>	16.8	12.3	0.8	0.2	—	—	6.9	4.9	17.7	11.8	82.3	11.8
<i>Manilkara udoido</i>	12.0	2.9	5.6	3.7	—	—	4.4	2.8	17.6	3.9	82.4	3.9
<i>Parinari laurina</i>	11.8	6.5	—	—	3.3	1.9	1.3	1.0	16.4	6.4	83.6	6.4
<i>Bruguiera gymnorhiza</i>	11.6	11.2	0.4	0.4	—	—	6.3	6.3	12.0	11.0	88.0	11.0
<i>Semecarpus venenosa</i>	2.4	1.1	1.0	0.7	7.3	5.9	2.1	1.3	11.7	6.6	88.3	6.6
<i>Rhus taitensis</i>	9.4	4.9	2.3	2.0	—	—	1.8	1.3	11.7	6.5	88.3	6.5
<i>Rhizophora mucronata</i>	7.2	1.2	1.4	0.6	0.7	0.7	1.4	1.4	9.3	1.0	90.7	1.0
<i>Camptosperma brevipetiolata</i>	4.2	2.2	3.3	2.0	4.2	2.6	—	—	9.2	4.0	90.8	4.0
<i>Pinanga insignis</i>	1.2	1.1	0.1	0.1	0.1	0.1	0.1	0.1	1.4	1.1	98.6	1.1
<i>Cyathea nigricans</i>	—	—	—	—	1.3	1.3	—	—	1.3	1.3	98.7	1.4

Note: — = not observed.

**Figure 17—Number of live trees ≥ 1 inch diameter at breast height in Republic of Palau by composite epiphyte load.**

The swamp forest tree, *Barringtonia racemosa* (koranges), the tree fern, *Cyathea nigricans* (cheluu), and the canopy tree, *Maranthes corymbosa* (bkau), were the only three species of the 24 live tree species with sample sizes >30, composing 20 percent of all species observed with epiphytes, with mean epiphyte load composite scores greater than three (fig. 18). Three mangrove trees *Bruguiera gymnorhiza* (kodenges), *Rhizophora mucronata* (tebechel), and *R. apiculata* (bngaol) had the lowest mean composite epiphyte load scores, with essentially no epiphytes.

Growth, Mortality, and Removals

We estimated that there were 30,122,945 (SE = 2,973,055) new trees >1 inch DBH in Palau from 2003 to 2014; 28,119,947 (SE = 3,093,398) trees that died; and 138,071 (SE = 87,848) trees that were removed. The sum of these categories resulted in a total net gain of 1,864,926 (SE =

3,499,253) trees overall, but the SE was about twice the size of the estimate, which means that we cannot be certain if there was an overall increase or an overall decrease in the number of trees in Palau during this timeframe. Among all forest communities across the main islands, there was a clear trend of more trees growing into the next largest diameter class with increasing diameter, and there appeared to be slightly more relative growth among the smallest and largest diameter classes but substantially less relative growth among midsize classes in Babeldaob forests compared to Koror/Rock Island/Peleliu/Angaur forests (fig. 19).

We estimated significant net increases in abundance for 18 tree species, and significant net decreases in the abundance of 17 species (with a SE/estimate ratio that was <0.9) between the 2003 and 2014 inventories (table 13). The native tree, *Macaranga carolinensis* (bedel), had

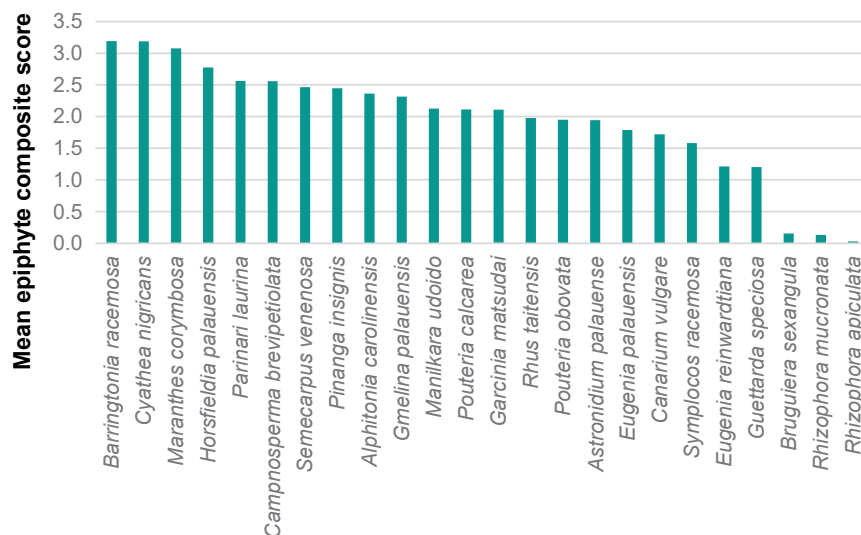


Figure 18—Mean composite epiphyte load score on trees ≥1 inch diameter at breast height in Republic of Palau by tree species (n ≥ 30).

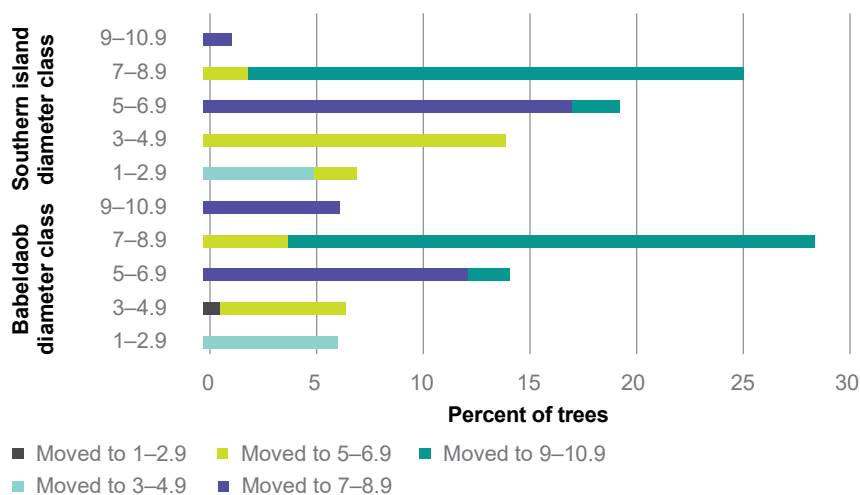


Figure 19—Percentage of trees that transitioned between diameter classes between 2003 and 2014 USDA Forest Service Forest Inventory and Analysis inventories on the southern islands (Koror, Rock Islands, Peleliu, Angaur) and Babeldaob in Republic of Palau.

the largest significant net loss in abundance followed by *Cocos nucifera* (lius) and *Calophyllum inophyllum* (btaches). The endemic tree, *Eugenia palauensis* (orenged), had the largest significant net gain in abundance followed by *Timonius mollis* and *Semecarpus venenosa* (tonget).

We estimated a 2,267,780-ton increase (SE = 178,353) in tree biomass (live, aboveground, and dry weight) from 2003 to 2014, a 1,055,143-ton loss (SE = 128,498) to tree mortality, and a 33,169-ton loss (SE = 22,674) to tree removals (Chave et al. 2014). The sum of these categories resulted in a total net gain of 1,179,467 tons (SE = 176,947) of tree biomass. The weight of forest carbon (total, gained, or lost) is half (0.5) the weight of the respective biomass.

Fifty-one tree species had significant gains in biomass, and 7 species had significant losses in biomass (table 14) between 2003 and 2014 inventories. *Pouteria obovata* (chelangel) and *Pinanga insignis* (chebouch) had the largest significant net increases in biomass between inventories, while the two dominant canopy species, *Camposperma brevipetiolata* (kalel a charm) and *Maranthes corymbosa* (bkau), had the largest absolute net increases (table 14). The two species of chelangel (*Pouteria*) are very similar, but *P. calcarea* is a Palauan endemic that occurs on limestone substrate and *P. obovata* occurs on volcanic substrate. *Swietenia mahagoni* (mahongani), or planted mahogany, was in the top 15 species by significant net change

in biomass and had a net increase of nearly 3,000 tons of biomass annually. The species with the largest significant net loss of biomass was *Macaranga carolinensis* (bedel), and *Cocos nucifera* (lius) had the largest absolute net loss.

In 2014, 5.5 percent (SE = 0.7) of all trees ≥ 5 inch DBH were standing dead trees, or snags, which was slightly higher than in 2003 (4.7 percent [SE = 0.7]) (Donnegan et al. 2007). We inventoried 39 species of standing dead trees that were ≥ 1 inch DBH. The most common species of standing dead trees were *Cyathea nigricans* (cheluu) and *Rhizophora mucronata* (tebechel), each composing 9.1 percent of all inventoried standing dead trees, followed by *Maranthes corymbosa* (bkau), *Pinanga insignis* (chebouch), and *Rhus taitensis* (cheues) which accounted for 6.4 percent each (fig. 20). Mortality clearly declined as diameter class increased; in other words, the smallest trees died most frequently (fig. 21).

Removed trees composed <0.5 percent of all inventoried trees in 2014. There were only three tree species removed by people between the 2003 and 2014 inventories: *Bruguiera gymnorhiza* (kodenges), *Dolichandrone spathacea* (rriu), and *Gmelina* sp. Another three species, *Areca catechu* (buuch), *Cocos nucifera* (lius), and *Manilkara udoido* (udeuid), were reported killed as a result of silvicultural or land clearing activity.

Table 13—Growth, mortality, removals, and net change in abundance (mean and sampling error [SE]) in Republic of Palau from 2003 to 2014 by tree species with ratio of SE/estimate <0.9 for net change sorted by confidence in the estimate (greatest to least)

Scientific name	Palauan common name	2003		2014		Gross growth		Mortality		Removals		Net change	
		Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
<i>Macaranga carolinensis</i>	Bedel	4,616,964	1,575,155	1,048,095	533,856	1,048,095	533,856	-4,616,964	1,575,155	—	—	-3,568,869	1,491,489
<i>Eugenia palauensis</i>	Orenged	1,622,957	493,725	2,336,961	675,095	725,241	361,457	-11,237	11,481	—	—	714,003	361,639
<i>Cocos nucifera</i>	Lius	331,848	168,982	215,752	107,800	—	—	-104,536	62,306	-11,560	11,523	-116,095	63,363
<i>Timonius mollis</i>	N/A	546,559	371,667	1,376,703	768,113	1,030,900	606,153	-200,755	171,196	—	—	830,144	469,980
<i>Semecarpus venenosa</i>	Tonget	1,792,480	480,061	2,411,726	533,648	837,735	314,341	-218,488	143,477	—	—	619,246	356,269
<i>Calophyllum inophyllum</i>	Btaches	466,437	222,099	119,186	44,749	—	—	-347,250	201,686	—	—	-347,250	201,686
<i>Parinari laurina</i>	Cheritem	1,296,105	577,334	1,660,429	718,616	422,123	242,372	-57,798	37,189	—	—	364,324	224,520
<i>Aidia cochinchinensis</i>	Kerumes	301,656	208,308	1,194,018	619,302	892,362	551,215	—	—	—	—	892,362	551,215
<i>Maranthes corymbosa</i>	Bkau	1,489,895	662,582	648,219	227,256	—	—	-841,676	523,366	—	—	-841,676	523,366
<i>Pinanga insignis</i>	Chebouch	11,121,846	2,132,172	12,762,195	2,377,395	3,270,999	959,958	-1,630,650	572,119	—	—	1,640,349	1,046,749
<i>Osmoxylon oliveri</i>	Kesiamel	789,741	605,375	1,919,356	1,188,349	1,140,853	727,117	-11,237	11,481	—	—	1,129,615	727,580
Tree unknown	N/A	242,082	181,356	587,885	365,897	345,803	224,081	—	—	—	—	345,803	224,081
<i>Timonius subauritus</i>	Blauelked	908,479	601,410	1,247,771	769,148	339,293	222,128	—	—	—	—	339,293	222,128
<i>Eugenia</i> spp.	N/A	294,823	202,209	—	—	—	—	-294,823	202,209	—	—	-294,823	202,209
<i>Elaeocarpus joga</i>	Dekemerir	691,928	353,507	229,260	78,307	—	—	-462,668	321,547	—	—	-462,668	321,547
<i>Pouteria calcarea</i>	Chelangel	783,435	476,267	1,771,095	875,128	1,204,532	734,348	-216,872	184,939	—	—	987,661	687,135
<i>Cerbera manghas</i>	Chemeridech	147,698	63,076	431,283	206,826	283,585	202,329	—	—	—	—	283,585	202,329
<i>Polyscias macgillivrayi</i>	Bngei	138,537	141,538	422,123	317,861	283,585	202,329	—	—	—	—	283,585	202,329
<i>Guettarda speciosa</i>	Diau	1,551,629	714,102	1,117,947	584,611	—	—	-433,682	317,852	—	—	-433,682	317,852
<i>Heterospathe elata</i>	Demallei	194,724	149,751	11,237	11,481	—	—	-183,487	146,355	—	—	-183,487	146,355

Table 13 (continued)—Growth, mortality, removals, and net change in abundance (mean and sampling error [SE]) in Republic of Palau from 2003 to 2014 by tree species with ratio of SE/estimate <0.9 for net change sorted by confidence in the estimate (greatest to least)

Scientific name	Palauan common name	2003		2014		Gross growth		Mortality		Removals		Net change	
		Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
<i>Pleomele hawaiiensis</i>	Hawaii hala pepe	228,109	185,295	16,116	13,743	—	—	-211,993	171,580	—	—	-211,993	171,580
<i>Pandanus tectorius</i>	Ongorraked	1,054,031	609,537	757,886	414,655	70,823	37,364	-366,968	233,170	—	—	-296,145	240,105
<i>Rhizophora apiculata</i>	Bengaol	1,280,105	958,788	2,719,027	1,675,455	1,607,089	1,193,091	-168,167	156,050	—	—	1,438,922	1,181,157
<i>Casuarina equisetifolia</i>	Ngas	32,232	18,438	16,116	13,743	—	—	-16,116	13,743	—	—	-16,116	13,743
<i>Syzygium samarangense</i>	Rebotel	416,624	255,747	400,508	253,854	—	—	-16,116	13,743	—	—	-16,116	13,743
<i>Hernandia sonora</i>	Doko	—	—	200,755	171,196	200,755	171,196	—	—	—	—	200,755	171,196
<i>Terminalia catappa</i>	Milich	44,950	35,695	245,705	174,877	200,755	171,196	—	—	—	—	200,755	171,196
<i>Allophylus timorensis</i>	Chebeludes	—	—	200,755	171,196	200,755	171,196	—	—	—	—	200,755	171,196
<i>Casearia cauliflora</i>	N/A	11,560	11,523	212,315	171,583	200,755	171,196	—	—	—	—	200,755	171,196
<i>Pongamia pinnata</i>	Kisaks	200,755	171,196	—	—	—	—	-200,755	171,196	—	—	-200,755	171,196
<i>Barringtonia asiatica</i>	Bduul	232,988	198,682	16,116	13,743	—	—	-216,872	184,939	—	—	-216,872	184,939
<i>Timonius timon</i>	Liberal	1,252,881	1,053,375	1,036,009	868,455	—	—	-216,872	184,939	—	—	-216,872	184,939
<i>Horsfieldia palauensis</i>	Chersachel	3,518,681	880,984	2,948,201	704,018	428,634	245,151	-999,114	422,649	—	—	-570,480	503,009
<i>Ficus tinctoria</i>	Oseked	992,388	861,556	16,116	13,743	—	—	-976,272	861,446	—	—	-976,272	861,446
<i>Fagraea ksid</i>	Ksid	137,105	67,371	374,649	220,833	260,664	212,738	-23,119	15,952	—	—	237,544	212,738

Note: — = not observed.

Table 14—Growth, mortality, removals, and net change in biomass (mean and sample error [SE]) (live, aboveground, and dry weight in tons) in Republic of Palau from 2003 to 2014 by tree species with ratio of SE/estimate <0.9 for net change sorted by confidence in the estimate (greatest to least)

Scientific name	Palauan common name	2003		2014		Gross growth		Mortality		Removals		Net change	
		Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
<i>Pouteria obovata</i>	Chelangel	62,432	18,035	87,490	23,524	26,353	9,495	-1,296	1,292	—	—	25,057	9,421
<i>Pinanga insignis</i>	Chebouch	373,656	72,013	467,382	86,737	149,366	33,802	-55,640	21,280	—	—	93,726	37,362
<i>Symplocos racemosa</i>	Chebtui	26,716	9,083	50,363	17,109	25,118	9,841	-1,471	1,179	—	—	23,648	9,931
<i>Campanosperma brevipetiolata</i>	Kalel a charm	385,992	108,451	547,001	169,663	195,310	65,215	-34,301	19,658	—	—	161,009	68,184
<i>Pouteria calcarea</i>	Chelangel	156,675	61,726	244,250	96,851	98,093	44,652	-10,518	8,970	—	—	87,575	37,153
<i>Astronidium palauense</i>	Meskui	68,860	31,673	83,850	32,650	25,383	9,380	-10,393	7,233	—	—	14,990	6,832
<i>Cerbera manghas</i>	Chemeridech	33,699	15,984	47,823	22,018	14,125	6,856	—	—	—	—	14,125	6,856
<i>Maranthes corymbosa</i>	Bkau	829,464	222,405	928,417	254,149	278,929	88,802	-179,976	71,287	—	—	98,953	49,419
<i>Aidia cochinchinensis</i>	Kerumes	1,559	1,128	3,250	1,750	1,691	867	—	—	—	—	1,691	867
<i>Timonius mollis</i>	N/A	816	622	3,145	1,763	2,421	1,255	-93	79	—	—	2,329	1,205
<i>Semecarpus venenosa</i>	Tonget	62,106	14,656	82,283	19,033	30,947	8,866	-10,770	5,332	—	—	20,177	10,500
<i>Swietenia mahagoni</i>	Mahongani	17,552	9,157	47,982	24,157	31,524	16,499	-1,094	1,090	—	—	30,430	15,872
<i>Eugenia palauensis</i>	Orenged	130,457	56,956	158,152	69,322	31,146	17,795	-3,451	3,526	—	—	27,695	14,489
<i>Buchanania palauensis</i>	Omail	65,868	45,524	83,454	53,810	17,586	9,533	—	—	—	—	17,586	9,533
<i>Fagraea ksid</i>	Ksid	61,257	32,418	104,926	51,823	48,529	23,709	-4,860	3,726	—	—	43,669	23,681
<i>Macaranga carolinensis</i>	Bedel	29,081	10,984	7,606	4,670	14,937	5,344	-36,412	13,486	—	—	-21,474	11,958
<i>Rhizophora apiculata</i>	Bngaol	133,717	103,900	184,336	125,685	55,101	31,033	-4,482	3,522	—	—	50,619	28,348
<i>Canarium vulgare</i>	Mesecheues	203,596	101,748	242,058	119,125	38,732	22,055	-270	269	—	—	38,462	21,869

Table 14 (continued)—Growth, mortality, removals, and net change in biomass (mean and sample error [SE]) (live, aboveground, and dry weight in tons) in Republic of Palau from 2003 to 2014 by tree species with ratio of SE/estimate <0.9 for net change sorted by confidence in the estimate (greatest to least)

Scientific name	Palauan common name	2003		2014		Gross growth		Mortality		Removals		Net change	
		Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
<i>Canarium hirsutum</i>	Mesecheues	37,335	20,360	49,540	26,106	14,050	7,113	-1,844	1,884	—	—	12,205	7,298
<i>Guettarda speciosa</i>	Blau	144,122	70,930	166,320	80,078	30,172	16,538	-7,973	4,596	—	—	22,198	13,629
Tree unknown	N/A	53,581	34,128	77,195	48,330	23,614	14,714	—	—	—	—	23,614	14,714
<i>Cocos nucifera</i>	Lius	161,111	80,996	113,258	57,419	11,801	9,541	-52,802	31,379	-6,852	6,830	-47,853	29,959
<i>Eugenia</i> spp.	N/A	8,154	5,188	—	—	544	408	-8,698	5,400	—	—	-8,154	5,188
<i>Timonius subauritus</i>	Blauelked	9,518	7,580	19,764	13,611	10,246	6,556	—	—	—	—	10,246	6,556
<i>Ficus microcarpa</i>	Lulk	124,556	94,239	146,349	106,886	21,793	14,097	—	—	—	—	21,793	14,097
<i>Rhizophora mucronata</i>	Tebechel	278,009	196,828	312,024	205,374	72,870	45,332	-38,855	38,730	—	—	34,015	22,212
<i>Pisonia grandis</i>	Mesbesibech	79,604	67,777	91,540	75,344	11,937	8,155	—	—	—	—	11,937	8,155
<i>Artocarpus mariannensis</i>	Chebiei	101,743	66,938	124,475	82,265	22,732	15,587	—	—	—	—	22,732	15,587
<i>Pleomele hawaiiensis</i>	Hawaii hala pepe	15,890	10,618	2,346	2,000	878	749	-14,422	9,885	—	—	-13,544	9,499
<i>Aglaia mariannensis</i>	Titimel	9,760	6,576	14,055	9,572	4,295	3,020	—	—	—	—	4,295	3,020
<i>Meryta senffiana</i>	Omechidel	1,071	1,068	1,573	1,376	502	354	—	—	—	—	502	354
<i>Buchanania engleriana</i>	Omail	6,844	3,336	12,308	5,214	7,349	3,833	-1,885	1,878	—	—	5,464	3,880
<i>Gmelina palawensis</i>	Blacheos	188,428	44,786	210,583	48,115	44,297	11,995	-22,142	11,897	—	—	22,156	16,079
<i>Xylocarpus granatum</i>	Meduulokebong	34,197	28,712	39,805	32,722	6,540	4,977	-932	929	—	—	5,608	4,125
<i>Heterospathe elata</i>	Demailei	8,508	6,605	605	618	-35	124	-7,868	5,964	—	—	-7,903	6,034
<i>Hibiscus tiliaceus</i>	Chermall	22,065	16,357	60,792	46,259	56,674	39,924	-17,947	15,668	—	—	38,727	29,962
<i>Drypetes nitida</i>	Keuert	39,486	20,752	46,610	25,480	7,766	5,477	-642	640	—	—	7,125	5,514
<i>Cer tops tagal</i>	Biut	28,299	25,683	37,534	32,728	9,683	7,612	-448	446	—	—	9,235	7,188

Table 14 (continued)—Growth, mortality, removals, and net change in biomass (mean and sample error [SE]) (live, aboveground, and dry weight in tons) in Republic of Palau from 2003 to 2014 by tree species with ratio of SE/estimate <0.9 for net change sorted by confidence in the estimate (greatest to least)

Scientific name	Palauan common name	2003		2014		Gross growth		Mortality		Removals		Net change	
		Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
<i>Osmoxylon oliveri</i>	Kesiamei	5,300	2,706	10,417	6,275	5,518	3,962	-401	409	—	—	5,118	3,999
<i>Horsfieldia amklaal</i>	Chemeklachel	312,152	181,598	349,318	187,651	40,993	28,938	-3,826	2,678	—	—	37,166	29,097
<i>Horsfieldia palauensis</i>	Chersachel	113,775	27,481	128,579	27,122	27,076	9,455	-12,271	7,792	—	—	14,804	11,643
<i>Calophyllum pelewense</i>	Chesemolech	20,229	14,608	32,859	24,112	14,274	9,813	-1,645	1,639	—	—	12,630	10,013
<i>Rhus taitensis</i>	Cheues	92,318	30,642	114,927	30,624	62,893	16,700	-40,284	20,883	—	—	22,609	18,333
<i>Kayea pacifica</i>	Ketenguit	6,178	3,389	9,429	5,634	3,251	2,643	—	—	—	—	3,251	2,643
<i>Ormosia calavensis</i>	Edebsungelkel	6,120	5,138	25,661	21,484	19,542	16,346	—	—	—	—	19,542	16,346
<i>Glochidion</i> spp.	N/A	19,997	18,646	21,652	20,024	2,081	1,430	-427	436	—	—	1,654	1,396
<i>Bruguiera gymnorrhiza</i>	Kodenges	134,860	60,953	152,805	71,374	36,589	19,519	-14,016	8,126	-4,628	4,613	17,945	15,288
<i>Barringtonia asiatica</i>	Bduul	8,460	7,215	6,431	5,484	2,707	2,309	-4,736	4,039	—	—	-2,029	1,730
<i>Hernandia sonora</i>	Doko	—	—	846	722	846	722	—	—	—	—	846	722
<i>Neisosperma oppositifolia</i>	Uauch	9,044	7,712	15,029	12,816	5,985	5,104	—	—	—	—	5,985	5,104
<i>Dodonaea viscosa</i>	Mesechelangel	17,766	15,150	20,837	17,769	3,071	2,619	—	—	—	—	3,071	2,619
<i>Pongamia pinnata</i>	Kisaks	215	183	—	—	200	171	-415	354	—	—	-215	183
<i>Allophylus timorensis</i>	Chebeludes	—	—	326	278	326	278	—	—	—	—	326	278
<i>Polyscias macgillivrayi</i>	Bngei	880	899	1,887	1,750	1,007	861	—	—	—	—	1,007	861
<i>Nephelium lappaceum</i>	Rambotang	4,239	3,029	7,130	5,317	2,892	2,482	—	—	—	—	2,892	2,482
<i>Parinari laurina</i>	Cheritem	120,395	48,387	135,949	56,308	31,234	13,151	-15,680	10,184	—	—	15,554	13,579
<i>Anacolosa gluchidiiformis</i>	Churalanguis	2,256	1,679	3,659	2,868	1,402	1,228	—	—	—	—	1,402	1,228
<i>Sterculia palauensis</i>	N/A	7,611	6,021	11,288	9,271	3,678	3,292	—	—	—	—	3,678	3,292

Note: — = not observed.

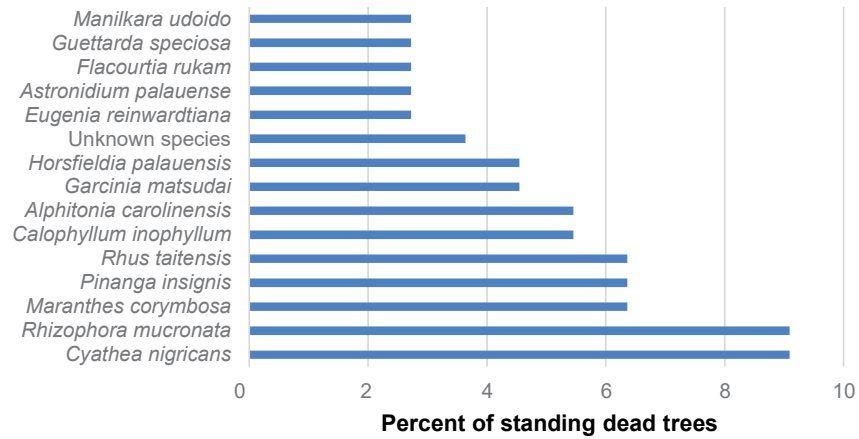


Figure 20—Dead trees inventoried in Republic of Palau by species that composed at least 2 percent of standing dead trees inventoried.

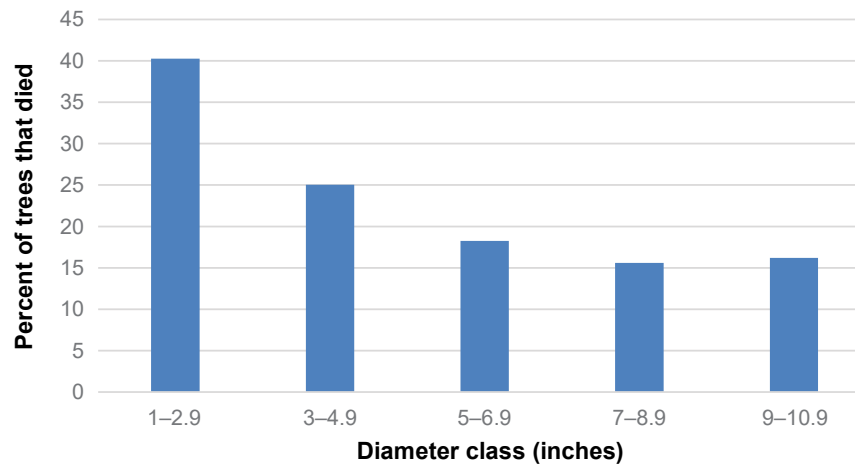


Figure 21—Trees that died between 2003 and 2014 USDA Forest Service Forest Inventory and Analysis inventories by diameter class in Republic of Palau.

Forest Structure

Stand-Size Class

The USDA Forest Service FIA program allocates all forests to six stand-size classes based on the predominant size of all live trees and saplings. Forests inventoried in Palau were all considered hardwood forests, with the following stand-size classes: (1) 1–4.9 inches DBH, (2) 5–10.9 inches DBH, (3) 11–19.9 inches DBH, (4) 20–39.9 inches DBH, and (5) ≥ 40 inches DBH. Most of the forest area was defined as stand-size class 2 (table 15). We did not encounter any nonstocked, class 4, or class 5 forest plots in Palau.

Table 15—Forest area (mean and sample error [SE]) in Republic of Palau by stand-size class

Stand-size class (DBH)	Forest area	SE
	PERCENT	
Nonstocked	—	—
1 (1.0–4.9 inches)	12.7	4.1
2 (5.0–10.9 inches)	65.3	6.2
3 (11.0–19.9 inches)	22.0	5.5
4 (20.0–39.9 inches)	—	—
5 (≥ 40 inches)	—	—

Note: DBH = diameter at breast height, — = not observed.

Volume, Biomass, Carbon, Stem Density, Basal Area

In 2014, we estimated 261,859,275 cubic feet (SE = 24,451,318) of live tree volume and 8,636,959 tons (SE = 685,276) of live, dry, aboveground biomass (4,318,480 tons of carbon). Strand forest (two plots on the Rock Islands) had the lowest estimated stem density (trees per acre), highest basal area (square feet per acre), and highest volume per acre (cubic feet per acre) of the three forest communities inventoried in Palau (table 16). Mangroves and lowland forest had similarly high stem density with around 1,000 trees per acre. There were no significant changes in estimated mean stem density between the 2003 and 2014 inventories, but there was a significant increase in basal area (table 17).

Vegetation Profile

The vegetation profile data that we collected on each subplot included two different datasets: (1) dominant vascular species composition and (2) growth habit by vegetation height layer. We collected dominant vascular species composition for the four most abundant plant species in each growth habit (including grasses, shrubs, forbs, and tree seedlings and saplings) that meet a 3-percent cover threshold. The height layer is listed where the most species cover occurs.

Table 16—Stem density, basal area, and volume per acre (mean and sample error [SE]) in Republic of Palau by forest community

Forest community	Stem density	SE	Basal area	SE	Volume	SE
	TREES PER ACRE		FEET ² PER ACRE		FEET ³ PER ACRE	
Strand forest	566	24	234	59	5,810	1,459
Mangrove swamps	1,011	278	146	27	2,187	622
Lowland tropical rainforest	946	54	138	9	2,454	225
All forest land	937	55	143	9	2,564	240

Table 17—Stem density, basal area, and volume per acre (mean and sample error [SE]) from 2003 and 2014 USDA Forest Service Forest Inventory and Analysis inventories for Republic of Palau forests

	2003	SE	2014	SE	Difference	SE
Stem density (trees per acre)	814	67	816	67	2	39
Basal area (feet ² per acre)	113	9	121	10	8	3

Table 18—Forest community area (mean and sample error [SE]) in Republic of Palau by the top 20 seedling/sapling species in lowland forest and the top 5 species in mangrove

Forest community	Scientific name	Palauan common name	Status	Forest area	SE
PERCENT					
Lowland tropical rainforest	<i>Pinanga insignis</i>	Ebouch	N	19.5	3.0
Lowland tropical rainforest	<i>Eugenia reiwnwardtiana</i>	Kesiil	N	3.6	1.0
Lowland tropical rainforest	<i>Horsfieldia palauensis</i>	Chersachel	P	3.5	0.7
Lowland tropical rainforest	<i>Parinari laurina</i>	Cheritem	N	2.4	1.2
Lowland tropical rainforest	<i>Astronidium palauense</i>	Mesekui	P	2.3	0.8
Lowland tropical rainforest	<i>Pandanus aimiriikensis</i>	Chertochet	P	2.2	0.5
Lowland tropical rainforest	<i>Macaranga carolinensis</i>	Bedel	N	1.9	0.9
Lowland tropical rainforest	<i>Hibisucs tileaceus</i>	Ermall	N	1.9	1.4
Lowland tropical rainforest	<i>Eugenia palauensis</i>	Orenged	P	1.7	0.4
Lowland tropical rainforest	<i>Garcinia matsudai</i>	Tilol	P	1.5	0.5
Lowland tropical rainforest	<i>Cyathea nigricans</i>	Cheluu	M	1.0	0.3
Lowland tropical rainforest	<i>Semecarpus venenosus</i>	Tonget	M	1.0	0.2
Lowland tropical rainforest	<i>Rinorea carolinensis</i>	N/A	N	0.9	0.4
Lowland tropical rainforest	<i>Glochidion ramiflorum</i>	Ngolm	U	0.8	0.3
Lowland tropical rainforest	<i>Pouteria calcarea</i>	Chelangel	P	0.8	0.5
Lowland tropical rainforest	<i>Manilkara udoido</i>	Edeuid	P	0.7	0.4
Lowland tropical rainforest	<i>Symplocos racemosa</i>	Chebtui	N	0.7	0.4
Lowland tropical rainforest	<i>Barringtonia racemosa</i>	Koranges	N	0.7	0.5
Lowland tropical rainforest	<i>Osmoxylon oliveri</i>	Kesiamel	P	0.7	0.4
Lowland tropical rainforest	<i>Pandanus tectorius</i>	Ongorraked	N	0.7	0.4
Mangrove swamp	<i>Rhizophora apiculata</i>	Bngaol	N	33.3	14.0
Mangrove swamp	<i>Bruguiera gymnorhiza</i>	Kodenges	N	5.5	2.8
Mangrove swamp	<i>Rhizophora mucronata</i>	Tebechel	N	4.9	3.0
Mangrove swamp	<i>Xylocarpus granatum</i>	Meduulokebong	N	3.6	2.1
Mangrove swamp	<i>Ceriops tagal</i>	Biut	N	2.9	1.9

Note: N = native, P = endemic to Palau, M = endemic to Micronesia, U = unresolved, NA = not applicable.
Status from Balick and Kitalong 2020.

The percentage of cover for each growth habit is also described by height layer with an overall estimate across the entire subplot. Table 18 shows the top 20 species in low-land forest and the top 5 species in mangroves by percentage of forest community area.

Dominant Vascular Plant Species Composition

We recorded 196 dominant vascular plant species in Palau forests in 2014; 132 were recorded in 2003 (Donnegan et al. 2007). We recorded more dominant species in lowland

forest than in other forest communities. About half of the most dominant plant species that we surveyed in Palau were trees; 17 percent were shrubs; 27 percent were forbs (including ferns); and 4 percent were grasses, or grass-like plants. Among the 20 most recorded tree seedling/sapling species, 7 were endemic to Palau, and 2 were endemic to Micronesia, while no Palauan endemics (and 3 Micronesian endemics) were among the 20 most recorded nontree species (tables 18 and 19).

Seedlings and saplings of the palm, *Pinanga insignis* (chebouch), covered the most forest area by dominant

vascular plant species. *P. insignis* commonly dominates the subcanopy of lowland tropical rainforest, especially on Babeldaob (table 18). Other dominant understory tree species in lowland forest included *Eugenia reinwardtiana* (kesiil) and the endemic *Horsfieldia palauensis* (chersachel), both of which occur on volcanic and limestone substrates. *Rhizophora apiculata* (bngaol) seedlings/saplings were dominant in mangrove understory. We recorded *Freycinetia reineckeii* (iul), which resembles a climbing pandanus vine, among all height layers, mostly above 16 feet, and was the most widespread nontree plant species. The fern, *Dicranopteris linearis* (itouch), a common ground cover in forest and savanna, forms a thick litter layer that can prevent the spread of invasive species and appears to be

involved in the succession of bare or savanna areas to forest on volcanic soils (table 19) (Russell et al. 1998).

Growth Habit and Vegetation Height Layer

Tree seedlings and saplings composed more than three-quarters of the vegetation profile in Palau, with the greatest cover being >16 feet high (table 20). In general, vegetation cover was greater as height increased from the ground to ≥16 feet (table 21). Lowland forest had significantly more cover in all vegetation height layers and more coverage from shrubs, including woody vines, and grasses/grass-like plants than mangrove and strand forest (table 22). Mangrove had little cover from nontree growth habits and the lowest cover among forest communities at ≤2 feet.

Table 19—Total forest area (mean and sample error [SE]) in Republic of Palau by the top 20 nontree plant species and USDA Natural Resource Conservation Service growth habit

Scientific name	Palauan common name	Growth habit	Status	Total forest area	SE
				PERCENT	
<i>Freycinetia reineckeii</i>	Iul	Shrub (vine)	N	3.6	0.8
<i>Dicranopteris linearis</i>	Itouch	Vine, forb/herb (fern)	N	3.1	1.1
<i>Nephrolepis hirsutula</i>	Terroter	Forb/herb (fern)	N	2.2	1.2
<i>Schefflera elliptica</i>	Bungaruau	Shrub	N	1.7	0.7
<i>Ixora casei</i>	Kerdeu	Shrub	M	1.4	0.5
<i>Operculina turpethum</i>	N/A	Vine	N	1.2	0.6
<i>Connarus semidecandrus</i>	Chemecherasech	Vine	N	1.2	0.4
<i>Merremia peltata</i>	Kebeas	Forb (vine)	*	1.1	0.6
<i>Donax canniformis</i>	Temring	Forb	N	1.1	0.8
<i>Lophopyxis maingayi</i>	Chiutekill	Vine	N	1.0	0.5
<i>Epipremnum carolinense</i>	Toilal	Forb (vine)	M	1.0	0.3
<i>Thelypteris unita</i>	Kikuld	Forb/herb (fern)	N	1.0	0.5
<i>Alpinia carolinensis</i>	Tuarekiuid	Forb	M	0.9	0.4
Unknown woody vine	N/A	Vine	U	0.8	0.3
<i>Eriachne pallescens</i>	Oeskadran	Grass	N	0.7	0.4
<i>Nephrolepis biserrata</i>	Terroter	Forb/herb (fern)	N	0.7	0.4
<i>Asplenium nidus</i>	Buklbeluu	Forb/herb (fern)	N	0.7	0.2
<i>Piper fragile</i>	Kesebeluu	Forb/herb, vine	N	0.6	0.3
<i>Blechnum orientale</i>	Klorouikl	Forb (fern)	N	0.5	0.4
<i>Lycopodiella cernua</i>	Olecheuilabeab	Subshrub, forb/herb	N	0.5	0.2

Note: N = native, M = endemic to Micronesia, * = invasive, U = unresolved, NA = not applicable.
Status from Balick and Kitalong 2020.



Figure 22—Republic of Palau Division of Forestry, Bureau of Agriculture, Ministry of Natural Resources, Environment and Tourism project manager Gwen Sisior and Ngardok conservation officer Svetlana Kadoi collect vegetation cover data on a USDA Forest Service Forest Inventory and Analysis plot in Palau. Photo by Else Demeulenaere.

Table 20—Forest area (mean and sample error [SE]) in Republic of Palau by vegetation growth habit and vegetation height layer

Growth habit	Layer 1: 0.0–2.0 feet	SE	Layer 2: 2.1–6.0 feet	SE	Layer 3: 6.1–16 feet	SE	Layer 4: ≥16.1 feet	SE	Overall aerial	SE
	PERCENT									
Tree	12	2	19	2	42	2	64	3	79	2
Shrub	3	0	5	1	6	1	6	1	15	1
Grass	4	1	1	0	0	0	0	0	4	1
Forb	10	1	12	2	4	1	3	0	19	2

Table 21—Forest area (mean and sample error [SE]) covered by all growth habits in Republic of Palau by vegetation height layer and forest community

Layer	Strand forest	SE	Mangrove swamp	SE	Lowland tropical rainforest	SE
	PERCENT					
1 (0–2 feet)	16	7	4	1	34	2
2 (2.1–6 feet)	31	6	24	10	40	3
3 (6.1–16 feet)	27	3	36	9	56	2
4 (≥16.1 feet)	66	6	62	10	74	3
Overall aerial	102	14	89	3	121	3

Note: Overall aerial values include overlap of growth habits and vegetation height layers, indicating differences in structural complexity among forest communities.

Table 22—Forest area (mean and sample error [SE]) in Republic of Palau by growth habit and forest community

Growth habit	Strand forest	SE	Mangrove swamp	SE	Lowland tropical rainforest	SE
	PERCENT					
Tree	83	3	86	3	78	2
Shrub	0	0	2	1	18	2
Grass	—	—	0	0	4	2
Forb	19	11	1	0	21	2

Note: — = not observed.

Volcanic Versus Limestone Forests

Stem density, basal area, and volume per acre were all higher in limestone forests than in volcanic forests in Palau, with differences arising largely from high values in the Rock Islands (table 23). The Rock Islands had the highest values for stem density, basal area, and volume per acre, which may be because of a combination of the extremely rugged terrain and low levels of human activity compared with the high levels of human disturbance elsewhere in Palau over the past century from colonial and wartime activities and subsequent development. The limestone forests on Peleliu and Angaur had the lowest

values for stem density, basal area, and volume per acre, and both islands were particularly heavily damaged by World War II as well as Typhoon Bopha in late 2012.

There were 13.1 live tree species per plot (SE = 0.8) in volcanic forests (n = 40) and 17.1 species per plot (SE = 2.1) in limestone forests (n = 8) in Palau, with 4.1 more tree species per plot (SE = 2.2) in limestone forests.

Invasive Species

Invasive species are a threat to native biodiversity and forest health, which is why the FIA program incorporated an invasive plant species protocol in this

Table 23—Estimated stem density, basal area, and volume per acre (mean and sample error [SE]) in Republic of Palau by substrate type

Substrate	Stem density	SE	Basal area	SE	Volume	SE
	TREES PER ACRE		FEET² PER ACRE		FEET³ PER ACRE	
All limestone islands	1,237	168	175	30	3,353	674
Babeldaob/Koror volcanic	949	55	137	9	2,455	229
Pelilieu/Angaur limestone	799	79	83	23	1,554	627
Rock Islands limestone	1,558	191	242	20	4,669	644

Table 24—Forest area cover (mean and sample error [SE]) in Republic of Palau by invasive plant species

Invasive species scientific name	Palauan common name	Forest area	SE
PERCENT			
<i>Timonius timon</i>	Liberal	0.56	0.49
<i>Clidemia hirta</i>	Kui	0.10	0.03
<i>Adenanthera pavonina</i>	Lel a telengtungd	0.06	0.04
<i>Epipremnum pinnatum</i>		0.06	0.06
<i>Falcataria moluccana</i>	Ukall ra ngebard, arbasia	0.03	0.03
<i>Hyptis capitata</i>		0.02	0.02
<i>Clerodendrum quadriloculare</i>	Kleuang	0.01	0.01
<i>Leucaena leucocephala</i>	Telengtungd	0.00	0.00
Total		0.86	0.50

measurement cycle. Palau Forestry provided a list of priority invasive plants and trees to include in the inventory. We recorded any invasive plant species from the list that was observed. We recorded eight invasive plants species, which cumulatively covered about 0.9 percent (SE = 0.5) of Palau's total forest area (table 24). Thirteen percent (SE = 3.2) of the total forest area in Palau had at least one invasive plant species present. *Merremia peltata* (kebeas) is considered a native invasive plant species in Palau and was included when it covered at least 3 percent of subplot area (see “*Merremia peltata* [kebeas]” below).

Merremia peltata (kebeas)

Merremia peltata (kebeas) is a native vine in Palau, but it is potentially harmful to forest ecosystem function, and Palau Forestry has carried out control efforts on it; so it is invasive. Comparison between FIA inventories in 2003 (Donnegan et al. 2007) and 2014 indicate that the total forest area covered by *M. peltata* in Palau decreased by 1 percent (SE = 0.9) and its mean subplot cover decreased by 17 percent (SE = 2.5)

M. peltata responds rapidly to increased light availability and appears to have spread along the edge of forest along the perimeter highway on Babeldaob, competing with, engulfing, and killing many trees there (Republic of Palau 2010). Although it is clearly visible that *M. peltata* has affected the forest along the roadside, most of the FIA forest plots did not occur at the road edge, so estimates reflect trends of interior forest that are generally not subject to high light levels and therefore are less suitable for *M. peltata*.

2014 Intensified Vegetation Sampling Subinventory

In 2014, a followup FIA intensified vegetation inventory was conducted on a subset of FIA subplots (n = 15) on Babeldaob. All vascular plant species were identified to species (when possible) and percentages of cover by species and canopy height layer were measured (Lehman et al. 2014) for each subplot.² This subinventory picked up about 10 times the average number of plant species per subplot as the base inventory (69 species [SE = 4.1]) compared to 6.3 species (SE = 0.3) per full subplot (n = 51) in the same plots. This ratio of partial-to-full inventory (10 percent) is roughly comparable to the ratio of the total number of vascular plant species inventoried to the total number of plants described for Palau (15 percent), which demonstrates that the standard FIA protocol inventories a subset of total plant species richness (the four most abundant species by four growth habits) and that the flora of Palau is remarkably species rich. The authors of the follow-up study also reported percentages of plant species inventoried per subplot by native/endemic status, with a mean of 27 percent being endemic to Palau (range of 12 to 37 percent). The full inventory estimated 29 percent Palauan tree endemism. The range of percentages of

² Lehman, A.; Driscoll, M.; Tadao, V.; Costion, C.; Kitalong, A. 2014. Unpublished data from phase 3 plot measurements in lowland tropical rainforest FIA plots on Babeldaob Island, Palau. On file with U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forest Sciences Laboratory, 161 East 1st Avenue, Door 8, Anchorage, AK 99501-1639.

forest cover by growth habit reported were also reasonably close to the mean values from the full inventory, with trees and forbs covering the most forest area, shrubs/woody vines covering most of the remainder, and grasses/grass-like plants covering around 5 percent or less.

Conclusion

Overall, we found more evidence of disturbance in the forests of Palau in 2014 compared to 2003, but the forests were surprisingly intact despite being affected by two major typhoons in the previous 2 years. Given the typhoon occurrences, weather (wind) was understandably the largest category of disturbance to forest area, but it was only observed in lowland forest and one strand forest plot. It is somewhat surprising that more wind disturbance was not observed in mangroves as mangrove and strand forest can be expected to suffer the most direct wind and wave forces in typhoons, and considerable damage was locally observed in these areas on Babeldaob. However, there is less mangrove area and fewer plots were randomly sampled on the eastern side of the island, which received most of the typhoon damages. Weather damage to trees was also surprisingly uncommon compared to disease, which was the largest source of damage to individual trees. We only recorded tree disease as a plot-level disturbance, in which at least 25 percent of the stand was affected, for mangroves. However, there were many non-mangrove species and forest conditions that did not meet the threshold for which we recorded individual diseased trees (USDA FS 2014).

The typhoons seem to have differentially affected forest dynamics across the archipelago. There was substantially higher mortality in the 3-to-4.9-inch diameter class among all forest communities. In addition, transition from that class to the 5-to-6.9-inch diameter class was about twice as high on southern islands compared to Babeldaob. This appears to coincide with local observations during that time that forests on southern islands and Peleliu and Angaur especially experienced more severe forest impacts from the typhoons than did forests on Babeldaob, which could have led to more opportunities for small to mid-sized trees to grow into gaps with more light exposure.

Fire was also a major source of disturbance on Babeldaob. The percentage of disturbance from fire increased from zero observations between 1993 and 2003 (Donnegan et al. 2007) to 9 percent of total forest area on Babeldaob from 2003 to 2014 (from fire found

on four plots in northern Babeldaob). However, this is likely an overestimate as 10 years of actual fire monitoring on Babeldaob (2012–2021) indicate that about 1 percent of forest area was burned by fire during that decade (Dendy et al. 2022a).

Total forest area increased by about 4 percent according to forested plot changes between the 2003 (Donnegan et al. 2007) and 2014 inventories, with a 5.1 percent net increase on Babeldaob ($SE = 2.3$). Satellite-based comparisons were roughly similar. A historical land cover study of Babeldaob (1921–2014) showed a 2.6 percent net forest increase on the island from 2001 to 2014 (Dendy et al. 2022b). Global Forest Watch showed both forest loss and gain of roughly 1 percent over overlapping periods (2000–2014) on Babeldaob, and confirmed stand-level forest losses on Peleliu and Angaur after the typhoons (Hansen et al. 2013).

As with the 2003 FIA inventory (Donnegan et al. 2007), smaller sized trees continued to characterize Palau's forests in 2014. Most trees in 2014 were <5 inches DBH and <25 feet tall. Among island groups in lowland tropical rainforest, the Rock Islands had the highest percentage of trees >10 inches DBH, but also the highest stem density. Strand forest had the lowest stem density, highest basal area, and highest volume per acre compared to lowland forest and mangrove swamp. Lowland forest had the highest forest cover among communities from grasses/grass-like plants and shrubs, and more forest cover overall throughout the different canopy height layers, especially near the ground. Despite having high live canopy cover overall, more than 15 percent of lowland forest plots were in partial forest, which suggests that the forests in Palau are somewhat patchy. Given that mangrove and strand forest tend to grow in narrow bands along coastal areas, it is unsurprising that around half of strand and mangrove forest plots (50 to 57 percent) were in partial forest plots.

There were significant increases in mean basal area and biomass, and total biomass of live trees increased by about a million tons, or roughly 100,000 tons of tree biomass grown per year (50,000 tons of carbon). In terms of productivity, Palau's forests grew about 2.9 percent in tree biomass per year and lost about 1.4 percent of tree biomass to mortality, for a net increase of 1.5 percent per year. Little tree harvesting appears to have occurred during this time, and only three species were noted as harvested. There

were no observations of planted mahogany harvested from FIA plots, but the species grew in biomass by around 32,000 tons, with 1,000 tons lost to mortality. Forests in Palau appear to have been highly dynamic between 2003 and 2014, with about 2 million trees gained and lost per year.

Most of the species with the largest gains and losses in tree abundance or biomass were among the most abundant or dominant species. However, *Macaranga carolinensis* (bedel) had by far the largest loss of trees, despite being relatively uncommon and undominant. *M. carolinensis* is considered a “pioneer” species that colonizes disturbed areas quickly but later gives way to other species as the forest matures and closes canopy. This has likely happened across Babeldaob in areas that were disturbed during the construction of the perimeter highway and provides some evidence of forest expansion or maturation of pioneer vegetation into secondary forest between inventories. *Cocos nucifera* (lius) had the largest absolute loss of biomass among species, with high mortality relative to growth, most of which appears to be typhoon related, and makes sense given their concentration near the coasts.

Invasive species appear to play a minor role in Palau’s forests. Less than 1 percent of forest area was covered in invasive plant species. *Merremia peltata* (kebeas), a native invasive vine, declined within FIA plots, despite being a roadside nuisance in many areas. Pig damage affected less than 0.5 percent of island area. The coconut rhinoceros beetle, after being introduced in the 1940s, caused mortality of up to 50 percent of coconut trees, but has since been managed with natural pathogens for decades (Berringer 2007, Hochberg and Waage 1991). However, this beetle appears to have made a comeback in Palau, with 40 percent of estimated coconut trees ($n = 18$) having visible damage from the beetles in 2014, although no coconut tree deaths attributed to insects were observed in this inventory. Coconut rhinoceros beetle infestations have reportedly worsened since then, but as with *Merremia*, the data from interior forests is likely to differ from roadside observations, although coconut trees are generally less abundant there. We did not observe any other species from the list of Pacific Island pests/diseases of concern in Palau.

Endemic species’ contribution to forest structure and composition is clear in Palau’s forests, particularly from

trees in the lowland tropical rainforest. Thirty-seven percent of all estimated trees in Palau were endemic to Micronesia (and 29 percent were endemic to Palau). Eight out of the twenty most abundant tree species were endemic, nine out of the twenty most dominant tree seedlings/saplings were endemic, and six out of the twenty trees with the highest relative dominance were endemic. Endemic species of herbaceous understory plants are less common than endemic trees in Palau forests, with only three out of the twenty most widespread understory species being endemic.

The inventory only captured about 15 percent of Palau’s total floristic diversity because the current methods focus on collecting data on dominant understory species and forest structure. In a subinventory in which all species were identified, species in the orchid family (Orchidaceae) composed by far the largest group of species by family; most species of orchids in Palau cover a tiny percentage of forest area but are often endemic. There were no differences in dominant vascular plant species richness among island groups (or substrate), but differences in absolute plant species richness may exist. Lowland forest had the highest diversity among trees and nontree species compared to strand or mangrove forest, which is consistent with tropical rainforest and mangrove diversity patterns across the Pacific region (Mueller-Dombois and Fosberg 1998). The higher tree species richness per plot in limestone lowland forest compared to volcanic lowland forest appears to be because of fundamental ecological differences between substrate types (Mueller-Dombois and Fosberg 1998).

Palau’s forests have the highest plant diversity and live canopy cover in Micronesia and one of the highest rates of plant species endemism among island biodiversity hotspots globally (Costion and Lorence 2012, Dendy et al. 2020). They also provide a wide range of ecosystem services as well as benefits to nonhuman organisms, such as protection and creation of soil; provision of clean, fresh water; regulation of temperature; and production of food, medicine, and building materials (Republic of Palau 2010). As such, ongoing monitoring of forests in Palau through programs such as the FIA are important for detecting and responding to changes in Palau’s forest health.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	0.3048	Meters
Acres (ac)	0.405	Hectares
Cubic feet (ft ³)	0.0283	Cubic meters
Tons (ton)	0.907	Tonnes or megagrams
Square feet per acre (ft ² /ac)	0.229	Square meters per hectare
Cubic feet per acre (ft ³ /ac)	0.07	Cubic meters per hectare
Trees per acre	2.47	Trees per hectare
Degrees Fahrenheit	0.56 (°F – 32)	Degrees Celsius

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APPENDIX 1

Scientific and Palauan Common Names of Plants Found During Republic of Palau's 2014 Forest Inventory

Life form	Scientific name	Authority	Palauan common name
Trees	<i>Cocos nucifera</i>	L.	Lius
Trees	<i>Swietenia mahagoni</i>	(L.) Jacq.	Mahongani
Trees	<i>Adenanthera pavonina</i>	L.	Telengtungdallel
Trees	<i>Aglaia mariannensis</i>	Merr.	Mesecheues
Trees	<i>Aidia cochinchinensis</i>	Lour.	Kerumes
Trees	<i>Allophylus timorensis</i>	(DC.) Blume	Chebeludes
Trees	<i>Alphitonia carolinensis</i>	Hosok.	Chelebiob, chelebiiong
Trees	<i>Anacolosa glochidiiformis</i>	Kaneh. & Hatus.	Churalanguis
Trees	<i>Areca catechu</i>	L.	Buuch
Trees	<i>Artocarpus mariannensis</i>	Trécul	Chebiei, meduuliou
Trees	<i>Astronidium palauense</i>	(Kaneh.) Markgr.	Mesekui
Trees	<i>Badusa palauensis</i>	Valeton	Ralm
Trees	<i>Barringtonia asiatica</i>	(L.) Kurz	Bduul
Trees	<i>Barringtonia racemosa</i>	(L.) Spreng.	Koranges
Trees	<i>Bruguiera gymnorhiza</i>	L. Lam. ex Savigny	Kodenges ^a
Trees	<i>Buchanania engleriana</i>	Volkens	Omail
Trees	<i>Buchanania palawensis</i>	Lauterb.	Omail
Trees	<i>Calophyllum inophyllum</i>	L.	Btaches
Trees	<i>Calophyllum pelewense</i>	P.F. Stevens	Chesemolech
Trees	<i>Calophyllum soulattri</i>	Burm. f.	Olebtaches, btacheschol
Trees	<i>Campnosperma brevipetiolata</i>	Volkens	Kiu, kalel a charm
Trees	<i>Canarium hirsutum</i>	Willd.	Mesecheues
Trees	<i>Canarium vulgare</i>	Leenh.	Mesecheues
Trees	<i>Casearia cauliflora</i>	Volkens	
Trees	<i>Casuarina equisetifolia</i>	L.	Ngas
Trees	<i>Cerbera floribunda</i>	K. Schum.	Chemeridech
Trees	<i>Cerbera manghas</i>	L.	Chemeridech
Trees	<i>Ceriops tagal</i>	(Perr.) C.B. Rob.	Biut
Trees	<i>Cinnamomum carolinense</i>	Koidz.	Ochod
Trees	<i>Cleistanthus carolinianus</i>	Jabl.	
Trees	<i>Commersonia bartramia</i>	(L.) Merr.	Bebechelut
Trees	<i>Colona scabra</i>	(Sm.) Burret	Chuchab, cheriut
Trees	<i>Cyathea lunulata</i>	(G. Forst.) R.M. Tryon	Cheluu
Trees	<i>Cyathea nigricans</i>	Mett.	Cheluu
Trees	<i>Cynometra ramiflora</i>	L.	Ketenguit
Trees	<i>Diospyros blancoi</i>	A. DC.	Matib

^a*Bruguiera gymnorhiza* is listed as *sexangula* in the Pacific Islands Public Access Database (October 2021).

Life form	Scientific name	Authority	Palauan common name
Trees	<i>Diospyros ferrea</i>	(Willd.) Bakh.	
Trees	<i>Diospyros sandwicensis</i>	(A. DC.) Fosberg	
Trees	<i>Dodonaea viscosa</i>	Jacq.	Mesechelangel
Trees	<i>Dolichandrone spathacea</i>	(L. f.) K. Schum.	Rriu
Trees	<i>Dracaena multiflora</i>	Warb. ex Sarasin	Orredakl
Trees	<i>Drypetes nitida</i>	Kaneh.	Keuert
Trees	<i>Elaeocarpus joga</i>	Merr.	Dekemerir
Trees	<i>Eugenia javanica</i>	Merr. & L.M. Perry	Rebotel
Trees	<i>Eugenia palauensis</i>	Kaneh.	Orenged, mesekerrak
Trees	<i>Eugenia reinwardtiana</i>	(Blume) A. Cunn. ex DC.	Kesiil
Trees	<i>Fagraea berteriana</i>	A. Gray ex Benth.	Chelilai
Trees	<i>Fagraea ksid</i>	Gilg & Bened.	Ksid
Trees	<i>Ficus carica</i>	L.	Uosechelkall
Trees	<i>Ficus copiosa</i>	Steud.	Uosed
Trees	<i>Ficus microcarpa</i>	L.	Lulk
Trees	<i>Ficus scabra</i>	G. Forst.	
Trees	<i>Ficus</i>	L.	
Trees	<i>Ficus tinctoria</i>	G. Forst	Oseked
Trees	<i>Finschia chloroxantha</i>	Diels	
Trees	<i>Flacourtia rukam</i>	Zoll. & Moritzi	
Trees	<i>Garcinia matsudai</i>	Kaneh.	Tilol
Trees	<i>Garcinia rumiyo</i>	Kaneh.	Tilol
Trees	<i>Gironniera celtidifolia</i>	Gaudich.	Chelidu
Trees	<i>Glochidion ramiflorum</i>	J.R. & G. Forst.	Ngolm
Trees	<i>Glochidion</i>	J.R. Forst. & G. Forst.	
Trees	<i>Gmelina palawensis</i>	H.J. Lam	Blacheos
Trees	<i>Glochidion kanehirae</i>	Hosok.	Kesengelngolm
Trees	<i>Goniothalamus carolinensis</i>	Kaneh.	Chelideu
Trees	<i>Guettarda speciosa</i>	L.	Blau
Trees	<i>Gulubia palauensis</i>	(Becc.) H.E. Moore & Fosberg	Bochelauchererak
Trees	<i>Hernandia sonora</i>	L.	Doko
Trees	<i>Heterospathe elata</i>	Scheff.	Demailei, beokl
Trees	<i>Hibiscus tiliaceus</i>	L.	Chermall
Trees	<i>Horsfieldia amklaal</i>	Kaneh.	Chemeklachel, edumail
Trees	<i>Horsfieldia palauensis</i>	Kaneh.	Chersachel
Trees	<i>Inocarpus fagifer</i>	(Parkinson) Fosberg	Keam
Trees	<i>Intsia bijuga</i>	(Colebr.) Kuntze	Dort
Trees	<i>Kayea pacifica</i>	Hosok.	Ketenguit
Trees	<i>Lumnitzera littorea</i>	(Jack) Voigt	Mekekad
Trees	<i>Macaranga carolinensis</i>	Volkens	Bedel
Trees	<i>Mallotus tiliifolius</i>	(Blume) Müll.Arg.	Dachelcharm
Trees	<i>Mammea odorata</i>	(Raf.) Kosterm.	Ongolbesachel, kodebisech

Life form	Scientific name	Authority	Palauan common name
Trees	<i>Manilkara udooido</i>	Kaneh.	Udeuid
Trees	<i>Maranthes corymbosa</i>	Blume	Bkau
Trees	<i>Medusanthera carolinensis</i>	(Kaneh.) R.A. Howard	
Trees	<i>Meryta senffiana</i>	Volkens	Omechidel
Trees	<i>Millettia pinnata</i>	(L.) Panigrahi	Kisaks
Trees	<i>Morinda citrifolia</i>	L.	Ngel
Trees	<i>Morinda latibractea</i>	Valeton	Kesengelngel
Trees	<i>Morinda pedunculata</i>	Valeton	Kesengelngel
Trees	<i>Myristica hypargyrea</i>	(Kaneh.) W.J. de Wilde	
Trees	<i>Myrsine</i>	L.	
Trees	<i>Myrsine palauensis</i>	(Mez) Fosberg & Sachet	Kulsill
Trees	<i>Neisosperma oppositifolia</i>	(Lam.) Fosberg & Sachet	Uauch
Trees	<i>Nephelium lappaceum</i>	L.	Rambotang
Trees	<i>Neuburgia celebica</i>	(Koord.) Leenh.	Ralm
Trees	<i>Nypa fruticans</i>	Wurmb	Touechel
Trees	<i>Ophiorrhiza palauensis</i>	Valeton	Tielabekai
Trees	<i>Ormosia calavensis</i>	Blanco	Chedebsungel, chedebsungelked
Trees	<i>Osmoxylon oliveri</i>	Fosberg & Sachet	Kesiamel
Trees	<i>Osmoxylon pachyphyllum</i>	(Kaneh.) Fosberg & Sachet	Kesiamel
Trees	<i>Pandanus aimiriikensis</i>	Martelli	Chertochet
Trees	<i>Pandanus dubius</i>	Spreng.	Bekuu
Trees	<i>Pandanus kanehirae</i>	Martelli	Buuk
Trees	<i>Pandanus macrojeanneretia</i>	Martelli	
Trees	<i>Pandanus tectorius</i>	Parkinson ex Du Roi	Ongorraked
Trees	<i>Pandanus</i>	L. f.	
Trees	<i>Pangium edule</i>	Reinw.	Riamel
Trees	<i>Parinari laurina</i>	A. Gray	Cheritem
Trees	<i>Phaleria nisidai</i>	Kaneh.	Ongaël, delalakar
Trees	<i>Phyllanthus palauensis</i>	Hosok.	Udoud, dudurs
Trees	<i>Pinanga insignis</i>	Becc.	Chebouch
Trees	<i>Pisonia grandis</i>	R. Br.	Mesbesibech, chemoi
Trees	<i>Pleomele hawaiiensis</i>	O.Deg. & I. Deg	
Trees	<i>Polyscias macgillivrayi</i>	(Benth.) Harms	Bngei
Trees	<i>Polyscias</i>	J.R. Forst. & G. Forst.	
Trees	<i>Pouteria calcarea</i>	(Hosok.) Fosberg	Chelangel
Trees	<i>Pouteria obovata</i>	(R. Br.) Baehni	Chelangel
Trees	<i>Premna obtusifolia</i>	L.	Chosm
Trees	<i>Psychotria cheathamiana</i>	Fosberg	
Trees	<i>Psychotria kaduana</i>	(Cham. & Schltdl.) Fosberg	
Trees	<i>Psychotria leptothyrsa</i>	Valeton	
Trees	<i>Psychotria</i>	L.	

Life form	Scientific name	Authority	Palauan common name
Trees	<i>Pterocarpus indicus</i>	Willd.	Las
Trees	<i>Rhizophora apiculata</i>	Blume	Bngaol
Trees	<i>Rhizophora mucronata</i>	Lam.	Tebechel
Trees	<i>Rhus taitensis</i>	Guill.	Cheues
Trees	<i>Rinorea carolinensis</i>	Kaneh.	
Trees	<i>Scaevola sericea</i> var. <i>taccada</i>	(Gaertn.) Thieret & B. Lipscomb	Korrai, kirrai, railechol
Trees	<i>Semecarpus venenosa</i>	Volkens	Tonget
Trees	<i>Shirakiopsis indica</i>	(Willd.) Esser	Meskerekur
Trees	<i>Sonneratia alba</i>	Sm.	Urur
Trees	<i>Stemonurus ammui</i>	(Kaneh.) Sleumer	Ngmui
Trees	<i>Sterculia palauensis</i>	Kaneh.	
Trees	<i>Symplocos racemosa</i>	Roxb.	Chebtui
Trees	<i>Syzygium samarangense</i>	(Blume) Merr. & L.M. Perry	Rebotel
Trees	<i>Swietenia mahagoni</i>	(L.) Jacq.	Mahongani
Trees	<i>Terminalia catappa</i>	L.	Miich
Trees	<i>Timonius corymbosus</i>	Valeton	
Trees	<i>Timonius mollis</i>	Valeton	
Trees	<i>Timonius subauritus</i>	Valeton	Blauelked
Trees	<i>Timonius timon</i>	(Spreng.) Merr.	Liberal
Trees	<i>Trichospermum ledermannii</i>	Burret	Chelsau
Trees	<i>Tristiropsis obtusangula</i>	Radlk.	
Trees	<i>Vitex cofassus</i>	Reinw. ex Blume	Bars, beokel
Trees	<i>Xylocarpus granatum</i>	J. König	Meduulokebong
Forbs	<i>Abelmoschus moschatus</i>	Medik.	
Forbs	<i>Acanthus ilicifolius</i>	L.	Kollil
Forbs	<i>Alpinia carolinensis</i>	Koidz.	Tuarekiuid
Forbs	<i>Alocasia macrorrhizos</i>	(L.) G. Don	Bisechrabelau, bisech
Forbs	<i>Alpinia pubiflora</i>	(Benth.) K. Schum.	Sui
Forbs	<i>Asplenium polyodon</i>	G. Forst.	
Forbs	<i>Blechnum occidentale</i>	L.	
Forbs	<i>Blechnum orientale</i>	L.	Klorouikl
Forbs	<i>Caesalpinia bonduc</i>	(L.) Roxb.	
Forbs	<i>Clidemia hirta</i>	(L.) D. Don	Kui
Forbs	<i>Costus speciosus</i>	(J. Koenig)	
Forbs	<i>Cyclosorus heterocarpus</i>	(Blume) Ching	
Forbs	<i>Dalbergia hosokawae</i>	(Hosok.) Costion	Iult
Forbs	<i>Davallia solida</i>	(G. Forst.) Sw.	Likerbedaoch
Forbs	<i>Derris trifoliata</i>	Lour.	Kemokem
Forbs	<i>Dicranopteris linearis</i>	(Burm. f.) Underw.	Itouch
Forbs	<i>Donax canniformis</i>	(G. Forst.) K. Schum.	Temring
Forbs	<i>Epipremnum carolinense</i>	Volkens	Toilal

Life form	Scientific name	Authority	Palauan common name
Forbs	<i>Epipremnum pinnatum</i>	(L.) Engl.	
Forbs	<i>Freycinetia reineckeii</i>	Warb. ex Reinecke	Iul
Forbs	<i>Hanguana malayana</i>	(Jack) Merr.	Euais
Forbs	<i>Hyptis capitata</i>	Jacq.	Iganigakusa
Forbs	<i>Ipomoea indica</i>	(Burm.) Merr.	Oliimad
Forbs	<i>Lindsaea obtusa</i>	J. Sm. ex Hook.	
Forbs	<i>Lycopodiella cernua</i>	(L.) Pic. Serm.	Olecheuilabeab
Forbs	<i>Merremia peltata</i>	(L.) Merr.	Kebeas
Forbs	<i>Moerenhoutia laxa</i>	Schltr.	
Forbs	<i>Nephrolepis biserrata</i>	(SW.) Schott	Emarsuoch, teroter, ius
Forbs	<i>Nephrolepis hirsutula</i>	(J.R. Forst.) C. Presl	
Forbs	<i>Nepenthes mirabilis</i>	(Lour.) Druce	Meliik
Forbs	<i>Operculina</i>	Silva Manso	
Forbs	<i>Operculina turpethum</i>	(L.) Silva Manso	Onguchetrarekung, cheluchebeaur
Forbs	<i>Phymatosorus scolopendria</i>	(Burm. f.) Pic. Serm.	
Forbs	<i>Piper betle</i>	(Blume) Fosberg	Kebui
Forbs	<i>Piper fragile</i>	Benth.	Kesebibui
Forbs	<i>Piper hosokawae</i>	Fosberg	Oloch
Forbs	<i>Piper</i>	L.	
Forbs	<i>Polypodium punctatum</i>	(Thunb.) Mett	
Forbs	<i>Procris pedunculata</i>	(J.R. Forst. & G. Forst.) Wedd.	
Forbs	<i>Ptisana mertensiana</i>	(C. Presl) Murdock	Dermarm
Forbs	<i>Pyrrosia lanceolata</i>	(L.) Farw.	Albeluu
Forbs	<i>Schizaea dichotoma</i>	(L.) J. Sm.	Omoket
Forbs	<i>Scleria levis</i>	Retz.	Baklild
Forbs	<i>Stylosanthes guianensis</i>	(Aubl.) Sw.	
Forbs	<i>Tapeinidium amboynense</i>	(Hook.) C. Chr.	
Forbs	<i>Taenitis blechnoides</i>	(Willd.) Sw.	
Forbs	<i>Tectaria crenata</i>	Cav.	
Forbs	<i>Thelypteris dentata</i>	(Forssk.) E.P. St. John	
Forbs	<i>Thelypteris</i>	Schmidel	
Forbs	<i>Thelypteris maemonensis</i>	(W.H. Wagner & Grether) B.C. Stone	
Forbs	<i>Thelypteris parasitica</i>	(L.) Fosberg	
Forbs	<i>Thelypteris unita</i>	(L.) Morton	Kilkuld
Graminoids	<i>Eleusine indica</i>	(L.) Gaertn.	Deskim
Graminoids	<i>Eriachne pallescens</i>	R.Br.	
Graminoids	<i>Fimbristylis dichotoma</i>	(L.) Vahl	Kerngimesked
Graminoids	<i>Ischaemum indicum</i>	(Houtt.) Merr.	
Graminoids	<i>Rhynchospora rubra</i>	(Lour.) Makino	Bungadiiek
Graminoids	<i>Scleria levis</i>	Retz.	Baklild

Life form	Scientific name	Authority	Palauan common name
Graminoids	<i>Scleria polycarpa</i>	Boeckeler	
Shrubs	<i>Allophylus</i>	L.	
Shrubs	<i>Allophylus timorensis</i>	(DC.) Blume	Chebeludes
Shrubs	<i>Caesalpinia bonduc</i>	(L.) Roxb.	
Shrubs	<i>Callicarpa elegans</i>	Hayek	Keruiiau, cheruei
Shrubs	<i>Callicarpa</i>	L.	
Shrubs	<i>Cayratia trifolia</i>	(L.) Domin	Berdaki
Shrubs	<i>Clerodendrum quadriloculare</i>	(Blanco) Merr.	Kleuang
Shrubs	<i>Connarus semidecandrus</i>	Jack	Chemecherasech
Shrubs	<i>Derris elliptica</i>	(Wall.) Benth.	Dub
Shrubs	<i>Decaspermum fruticosum</i>	J.R. Forst.	Kertaku
Shrubs	<i>Derris</i>	Lour.	
Shrubs	<i>Derris trifoliata</i>	Lour.	Kemokem
Shrubs	<i>Eurya japonica</i>	Thunb.	Cheskiik
Shrubs	<i>Eurya japonica var. nitida</i>	(Korth.) Dyer	Cheskiik
Shrubs	<i>Ficus sagittata</i>	Vahl	Kulul
Shrubs	<i>Flagellaria indica</i>	L.	Bangarenguis
Shrubs	<i>Freycinetia reineckeii</i>	Warb. ex Reinecke	Iul
Shrubs	<i>Ixora casei</i>	Hance	Kerdeu
Shrubs	<i>Lophopyxis maingayi</i>	Hook.f.	Chiutekill, iutekill
Shrubs	<i>Loeseneriella macrantha</i>	(Korth.) A.C. Sm.	Kerangel
Shrubs	<i>Melicope denhamii</i>	(Seem.) T.G. Hartley	Kertub
Shrubs	<i>Melastoma malabathricum</i>	L.	Matakui
Shrubs	<i>Phyllanthus palauensis</i>	Hosok.	Udoud, dudurs
Shrubs	<i>Psychotria cheathamiana</i>	Fosberg	
Shrubs	<i>Psychotria diospyrifolia</i>	Kaneh.	
Shrubs	<i>Psychotria hombroniana</i>	(Baill.) Fosberg	
Shrubs	<i>Psychotria leptothyrsa</i>	Valeton	
Shrubs	<i>Salacia chinensis</i>	L.	Detimel
Shrubs	<i>Schefflera elliptica</i>	(Blume) Harms	Bungaruau, nguismedob
Shrubs	<i>Symplocos racemosa</i>	Roxb.	Chebtui
Shrubs	<i>Uncaria lanosa var. korrensis</i>	(Kaneh.) Ridsdale	Derikel
Shrubs	<i>Wikstroemia elliptica</i>	Merr.	Tebudel, rau

Source: Balick and Kitalong 2020.

Scientific Name Changes and Considerations

All tree species names and the 20 most recorded understory species in the inventory were checked against the most current species checklist for Palau (Balick and Kitalong 2020). Species are listed here as they appear in the Pacific Islands Public Access Database (October 2021), except for *Bruguiera gymnorhiza* L. Lam. (kodenges), which is listed as *sexangula* in the database. *B. sexangula* occurs across Southeast Asia and is invasive in Hawaii. It is almost indistinguishable from *B. gymnorhiza*, which has a broader distribution from Eastern Africa across Asia and occurs across Micronesia (Allen and Duke 2006). *Parinari laurina* is a synonym of the more commonly used *Atuna racemosa* Raf. (cheritem).

The two species of *Pouteria* (chelangel) in Micronesia have been transferred to the genus *Planchonella* Pierre. The Pacific Island species of *Glochidion* were transferred to the genus *Phyllanthus* L. Tree ferns formerly in the genus *Cyathea* (cheluu) are now in the genus *Sphaeropteris* Bernh. and *Horsfieldia amklaal*, which was formerly treated as endemic, is now the widespread *H. irya* (Gaertn.) Warb. (Craig and Lorence 2012). *Osmoxylon oliveri* (kesiamel) has been merged with *O. truncatum* (Kaneh.) Fosberg & Sachet (Costion and Plunkett 2016).

Additional Latin tree genus name changes since the 2014 inventory include *Eugenia palauensis* to *Syzygium*

palauense (Kaneh.) Hosok. (orenged), *Eugenia javanica* to *Syzygium samaragense* (Blume) Merr. & L.M. Perry (rebotel), *Millettia pinnata* to *Pongamia pinnata* (L.) Pierre (kisaks), and *Neisosperma oppositifolia* to *Ochrosia oppositifolia* (Lam.) K. Schum. (uach).

Additional tree species name changes include *Cinnamomum carolinense* to *C. pedatinervium* Meisn. (ochod), *Aidia cochinchinensis* to *A. racemosa* (Cav.) Tirveng. (kerumes), *Glochidion ramiflorum* to *Phyllanthus littoralis* (Blume) Müll. Arg. (ngolm), *Diospyros ferrea* to *D. palauensis* (Kaneh.) Fosberg, *Hernandia sonora* to *H. nymphaeifolia* (J. Presl) Kubitzki (doko), *Medusanthera carolinensis* to *M. laxiflora* (Miers) R.A. Howard, *Premna obtusifolia* to *P. serratifolia* L., and *Rinorea carolinensis* to *R. bengalensis* (Wall.) Kuntze.

Genus and species name changes for understory plant species include *Freycinetia reineckeii* to *F. villalobosii* (iul), *Nephrolepis hirsutula* to *N. obliterated* (R. Br.) J. Sm. (teroter), *Thelypteris unita* to *Sphaerostephanus unitus* (L.) Holttum (kikuld), *Blechnum orientale* to *Blechnopsis orientalis* (L.) C.Presl (klorouikl), and *Lycopodiella cernua* to *Palhinhea cernua* (L.) Frannco & Vasc. (olecheuilabeab).

Diospyros sandwichensis, *Psychotria kaduana*, and *Pleomele hawaiiensis* appear to have been recorded incorrectly as they are all endemic to Hawaii.

APPENDIX 2

Sample Error/Other Error

We report sample error of the mean (SE) for every estimate in this report, and it is crucial for assessing reliability of the estimate. The smaller the SE value is compared to the estimate, the more reliable the estimate is.

The value of SE added to and subtracted from the estimate creates a range (low value to high value) of confidence in which the true value of the population is likely to occur. If we repeatedly sampled the population and constructed a confidence interval in such a way, the true value would be within these confidence intervals about 68 percent of repeats. An approximately 95-percent confidence level interval can be created by multiplying the SE by 2 (and adding to and subtracting from the estimate). SE can be used to create intervals with any confidence level, as needed, using a statistical reference table (T table).

The USDA Forest Service Forest Inventory and Analysis (FIA) program follows a strict protocol to ensure high quality of data collected, including quality assurance and control procedures for measurements, data entry, and processing. However, measurement errors; species misidentifications; and mistakes in data entry, processing, and analysis still occur, although the program makes considerable effort to minimize them. We presented data with the precision of one decimal point, which in some cases results in totals not summing to exactly 100 percent.

Glossary

biodiversity—Variety and variability among living organisms and the ecological complexes in which they occur. Biodiversity can include genetic, species, and ecosystem diversity, including the number of different items and their relative frequencies (Glowka et al. 1994).

biomass—The aboveground weight of wood and bark in live trees, that are ≥ 1 inch diameter at breast height (DBH) from the ground to the tip of the tree, excluding all foliage. The weight of wood and bark in lateral limbs, secondary limbs, and twigs under 0.5 inch in diameter at the point of occurrence on sapling-size trees is included.

damage—Damage to trees caused by biotic agents such as insects, diseases, and animals or abiotic agents such as weather, fire, or mechanical equipment.

diameter at breast height (DBH)—The diameter of a tree stem, located above the ground (“breast height”) on the uphill side of a tree. The point of diameter measurement may vary on abnormally formed trees (USDA FS 2016).

disturbance—Any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment.

ecosystem—A spatially explicit, relatively homogeneous unit of the Earth that includes all interacting organisms and components of the abiotic environment within its boundaries. An ecosystem can be of any size: a log, a pond, a field, a forest, or the Earth’s biosphere (Helms 1998).

endemic—Plant species that are unique to a defined geographical location, e.g., species only found in Palau.

forb—A broad-leaved herbaceous plant, as distinguished from grasses, shrubs, and trees (USDA FS 2016).

forest community—A classification of forest land based on and named for the tree species that forms the plurality of live-tree cover that are not overtopped; delineated by the classification guide outlined in Mueller-Dombois and Fosberg (1998).

forest land—The USDA Forest Service Forest Inventory and Analysis program defines forest land as an area currently or formerly (within 30 years) exhibiting at least 10 percent crown cover of trees of any

size and which is not currently developed for nonforest use (USDA FS 2016). Forest land must occupy at least 1 ac and have a minimum continuous width of 120 ft.

grassland—Land on which the vegetation is dominated by grasses, grass-like plants, or forbs.

introduced species—species that are nonnative or naturalized and are introduced by humans and have established or expanded their populations (Balick and Kitalong 2020).

invasive species—Species that are nonnative to the ecosystem under consideration and that cause or are likely to cause economic or environmental harm or harm to human, animal, or plant health.

live trees—All living trees, including all size classes, all tree classes, and both commercial and noncommercial species listed in the USDA Forest Service Forest Inventory and Analysis field manual.

mortality—The death of trees from natural causes or following incidents such as storms, wildfire, or insect and disease epidemics (Helms 1998).

native species—Plant species that were native to a region prior to Euro-American settlement. (Balick and Kitalong 2020).

pathogen—An organism or virus directly capable of causing disease or mortality.

remote sensing—Capture of information about the Earth from a distant vantage point. The term is often associated with satellite imagery but also applies to aerial photography, airborne digital sensors, ground-based detectors, and other devices.

sampling error—Difference between a population value and a sample estimate that is attributable to the sample, as distinct from errors due to bias in estimation, errors in observation, etc. Sampling error is measured as the standard error of the sample estimate (Helms 1998).

sapling—A live tree 1 to 4.9 inches in diameter at breast height (DBH).

seedlings—Live trees < 1 inch DBH and ≥ 12 inches in height.

shrub—Perennial, multistem woody plant, usually < 13 to 16 feet in height, although under certain environmental conditions shrubs may be single-stem or > 16 feet in height. Includes succulents (e.g., cacti) and woody vines.

snag—A “standing dead tree.” To qualify as a snag, dead trees must be at least 1 inch diameter at breast height, have a bole that has an unbroken actual length of at least 4.5 ft, and have a lean angle that is less than 45 degrees from vertical.

stand-size class—A classification of stands based on tree size. Most trees in large-diameter stands are ≥ 11 inches diameter at breast height (DBH). Most trees in medium-diameter stands are ≥ 5 inches DBH but not as large as large-diameter trees. Most trees in small-diameter stands are < 5 inches DBH.

succession—The gradual supplanting of one community of plants by another.

tree—The USDA Forest Service Forest Inventory and Analysis (FIA) program defines a tree as a woody perennial plant, usually with a single, well-defined stem supporting a crown of leaves, with a minimum diameter at breast height of 3 inches (7.6 cm) and a minimum height of 15 ft (4.6 m) at maturity. Tally trees are defined as all live and standing dead trees (i.e., snags) in accessible forest land or measurable nonforest land condition classes. Any plant species on FIA's tree list in the current field manual is measured as a tree.

understory—Lowermost canopy layer, including shrubs, vines, and herbaceous vegetation such as forbs and graminoids.

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