Species Profiles for Pacific Island Agroforestry
www.traditionaltree.org

April 2006
ver. 2.1

# *Bruguiera gymnorrhiza* (large-leafed mangrove)

Rhizophoraceae (mangrove family)

***denges* (Palau); *jon* (Marshall Islands); large-leafed mangrove, oriental mangrove (English); orange mangrove (northern Australia); *ong* (Chuuk); *sohmw* (Pohnpei); *sraol* (Kosrae); *yangach* (Yap Islands)**

James A. Allen and Norman C. Duke


**Forest of large-leafed mangrove.**

## IN BRIEF

**Distribution** Found in Micronesia, Samoa, and the southwestern Pacific; widely distributed from the eastern coast of Africa through Asia to subtropical Australia.

**Size** Reaches 30–35 m (100–115 ft) in height, although commonly much shorter, around 7–20 m (22–62 ft).

**Habitat** Intertidal zones, 0–2 m (0–6.6 ft), or the elevation range between mean sea level and highest tide, with rainfall of 1000–8000 mm (40–315 in).

**Vegetation** Common associates on Pacific islands include other mangrove tree species.

**Soils** Wide range; trees thrive best in river estuaries.

**Growth rate** Less than 1 m/yr (3.3 ft/yr) in height.

**Main agroforestry uses** Soil stabilization, coastal protection, wildlife/marine habitat.

**Main products** Timber, dye, and traditional medicine.

**Yields** No data available.

**Intercropping** Recommended for planting together with other mangrove species.

**Invasive potential** Can be invasive; not recommended for planting outside of its natural range.

# INTRODUCTION

Large-leafed mangrove (*Bruguiera gymnorrhiza*) is one of the most important and widespread mangrove species in the Pacific. It is found in intertidal areas of the tropical Pacific region from Southeast Asia to the Ryukyu Islands of southern Japan into Micronesia and Polynesia (Samoa), and southward to subtropical Australia. Large-leafed mangrove thrives under a broad range of intertidal conditions, including salinity levels from near freshwater to full-strength seawater, and tolerates a range of flooding and other soil types. Typically, it is most common in the middle and upper intertidal zones, rather than in the lower intertidal zone or along the seaward edge of mangrove stands.

Some of the value of this species is difficult to separate out from the larger role played by mangrove species as a whole. Mangroves in general are believed to play vitally important roles in shoreline protection, enhancing water quality in nearshore environments (including over coral reefs), providing habitat for juvenile fish and other reef species, and supporting marine food chains through outwelling of carbon. Although the wood is the main part of the tree used in most of the Pacific, numerous uses for other parts of the tree including the propagules, leaves, and bark have been reported in the region.

# DISTRIBUTION

## Native range

Found in tropical intertidal areas from the eastern coast of Africa through Asia to the Ryukyu Islands of southern Japan, into Micronesia and Polynesia (Samoa), and southward to subtropical Australia (Queensland, New South Wales and Western Australia), it has the largest natural longitudinal range of all mangrove species.

Within the mangrove ecosystem, large-leafed mangrove is most commonly found in the middle and upper intertidal zones, rather than in the lower intertidal areas or outer seaward fringe.

## Current distribution

There is little evidence that large-leafed mangrove occurs widely outside of its natural range. It is possible that it occurs in the Hawaiian Islands, but recently the species of *Bruguiera* naturalized on O'ahu was found to be *B. sexangula*, not *B. gymnorrhiza* as previously reported (Allen et al. 2000).

# BOTANICAL DESCRIPTION

## Preferred scientific name

*Bruguiera gymnorrhiza* (L.) Lamk.

## Family

Rhizophoraceae (mangrove family)

## Non-preferred scientific names

*Brugiera gymnorrhiza* (L.) Lam., Tab. Encycl. 2: 517, t. 397. 1793 ("*gymnorhiza*"). (common misspelling)
*Rhizophora gymnorrhiza* L., Sp. Pl.: 443. 1753 ("*gymnorhiza*"); G. Forst., Fl. Ins. Austr.: 35, n. 201. 1786.
*Bruguiera rheedei* Bl., Enum. Pl. Jav.: 92. 1827 (*rheedii*).
*Brugiera rumphii* Bl., Mus. Bot. Lugd.-Bat. 1: 138. 1850.

## Common names

### Pacific

*denges* (Palau)
*jon* (Marshall Islands)
large-leafed mangrove, oriental mangrove (English)
*ong* (Chuuk, FSM)
orange mangrove (northern Australia)
*sohmw* (Pohnpei, FSM)
*sraol* (Kosrae, FSM)
*yangach* (Yap, FSM)

### Indian Ocean

*malkadol*, *sirikanda* (Sri Lanka: Sinhala)
*thuddu ponna*, *uredi* (Andhra Pradesh, India: Telugu)
*muia*, *mkoko wimbi* (Kenya, Tanzania, and Zanzibar, Mozambique: Kiswahili)

## Size

It is a medium to tall tree that may reach 30–35 m (100–115 ft) in height, although it is commonly much shorter. Diameters are commonly about 15–35 cm (6–14 in). Dwarfed stands have been reported for some locations (e.g., Pohnpei).

## Form

Large-leafed mangrove is normally a single-stemmed tree with short buttresses and characteristic "knee roots," (horizontal roots that occasionally form above-ground loops, presumably as an aid to gas exchange for the subsurface portions of the roots). It tends to be of shorter stature and more conical in shape on the seaward edge of stands or in areas of high salinity.

Bark is typically pale brown to grey (darker when wet), greater than 2 cm (0.8 in) thick, hard, and rough. Popula-

tions on Hainan Island (China) have distinctive bark characteristics with vertical fissures plus large flaky lenticels 2 cm (0.8 in) in diameter.

## Flowering

Flowers are perfect. Inflorescence has solitary flower buds, located in leaf axils, usually nodding, positioned at the first (or rarely second) node below the apical shoot. Mature flower bud when closed is 3.0–3.5 cm (1.2–1.4 in) long, 1.5–3.5 cm (0.6–1.4 in) wide. Calyx is typically reddish to almost scarlet, occasionally pale yellow, white or green, characteristically smooth or with grooves above lobe junctures, rarely ribbed, with 12–14 lobes, acutely pointed, narrow. Style is pale green, filiform, 3–4 lobes, about 20 mm (0.8 in) long and 1 mm (0.04 in) wide. Petals are bilobed (one third of total length), with hairy outer margins, creamy-white tend to orange-brown on maturation, number equals the number of calyx lobes, about 15 mm (0.6 in) long and 4 mm (0.16 in) wide. Bristle is between lobes, solitary, straight, up to 4 mm long. Bristles (3–4) are on tips of petal lobes, often curly, 3–4 mm (0.12–0.16 in) long. Stamens are creamy white to golden brown at maturity, about 12 mm (0.5 in) long. Peduncle is smooth, slender, curved, approximately 10 mm (0.4 in) long and 2–3 mm (0.08–0.12 in) wide. The flowering period is chiefly April to August in the southern hemisphere, and October to February in northern hemisphere.

**Foliage with flower buds and propagules showing typical red calyx form. Chuuk, Federated States of Micronesia.** PHOTO: N.C. DUKE

## Leaves

Leaves are opposite, simple, elliptical, dark green, and coriaceous (leathery), aggregated at the tips of apical shoots in clusters of about 12 leaves. Leaves are 8–22 cm (3–8.5 in) long and 5–8 cm (2–3 in) wide, with petioles of 2–4 cm (0.8–1.6 in). Leaf blades are elliptic tending to oblong, about 15 cm (6 in) long and 6 cm (2.4 in) wide, acute tip without mucro, petiole about 4 cm (1.6 in) long. Stipules (leaf sheaths) are green or yellowish, 4–8 cm (1.6–3.2 in) long. Apical shoots are about 6 cm (2.4 in) long. Leaf color, size, and shape enable *B. gymnorrhiza* trees to be distinguished from other *Bruguiera* spp. from a distance. It differs from *Rhizophora* spp. in the lack of mucronate leaf tip, longitudinal fold grooves along blade, and lack of cork wart spots. Leaf emergence occurs mainly from November to March in southern hemisphere, May to September in the northern hemisphere; marked declines in canopy density may occur during these months if rainfall is low. Leaf fall occurs chiefly over the wet summer period from October to March in the southern hemisphere, April to September in the northern hemisphere.

## Fruit

Large-leafed mangrove is viviparous, meaning that the species produces seeds that germinate on the parent plant. The dispersal unit, a viviparous seedling, is called a hypocotyl. There is no apparent fruit stage. Instead, a hypocotyl emerges singly from an attached mature calyx. Mature hypocotyls with attached calyx bodies are located at the third to fifth nodes below the apical shoot. The hypocotyl is cylindrical, elongate, stocky, dark green, coriaceous, with lon-

gitudinal ribbing giving an angular appearance, the root tip bluntly pointed, mature dimensions 15–25 cm (6–10 in) long and about 2 cm (0.8 in) wide. Expended calyces often remain attached after mature propagules fall from parent trees. "Fruiting," when mature hypocotyls fall, occurs January to February in the southern hemisphere, and July to August in the northern hemisphere.

### Seeds

Like all *Bruguiera* species, large-leafed mangrove is viviparous, meaning that the species produces seeds hidden in the mature calyx (post-flowering) that germinate on the parent plant. Just one hypocotyl is usually produced from each mature calyx, although on rare occasions twins may be observed.

### Rooting habit

Mature trees have distinctive, sturdy, above-ground knee-roots surrounding the stem base that anchor only shallowly in the sediments, to 1–2 m (3.3–6.6 ft) depth.

### Similar species

Large-leafed mangrove is most likely to be confused with other *Bruguiera* species/taxa where distributions overlap in the western Pacific. In particular, *B. gymnorrhiza* might be confused with *B. sexangula*, *B.* × *rhynchopetala*, *B. exaristata*, *B. parviflora*, or *B. cylindrica*.

**Mature hypocotyl and calyx attached to branch. Daintree River, NE Australia.** PHOTO: N.C. DUKE

***B. sexangula*** Often almost indistinguishable from *B. gymnorrhiza*. it has a solitary flower, calyx orangey-pink, usually ribbed rather than grooved above lobe junctures, like *B. gymnorrhiza*. Propagules tend to be much shorter, 6.5–9.0 cm (2.6–3.5 in). Populations in Hainan Island (China) have distinctive smoother bark with horizontal fissures plus small lenticels about 1 cm (0.4 in) in diameter.

***B.* × *rhynchopetala*** *B. gymnorrhiza* is also reported to hybridize with *B. sexangula*, giving progeny called *B.* × *rhynchopetala.* This hybrid taxon has intermediate and shared characters of *B. sexangula* and *B. gymnorrhiza*, with a solitary flower, calyx green with red blush, variably ribbed or grooved above lobe junctures. Propagules are indistinguishable from parental taxa. Populations in Hainan Island (China) have distinctive intermediate bark with horizontal and vertical fissures plus intermediate-sized lenticels 1–2 cm (0.4–0.8 in) in diameter.

***B. exaristata*** Solitary flowers also, but they are smaller, green never reddish, calyx ribbed with 8–10 spreading lobes compared to 12–13 for *B. gymnorrhiza*. Furthermore, unlike other solitary flower taxa, this species has no spine between petal lobes. Propagule distinctly ribbed, much shorter.

***B. parviflora*** Multiple flowers are in small groups, each having 7–8 short calyx lobes extending down from the narrow, elongate, ribbed calyx. Propagules substantially thinner, with elongate spaghetti-like appearance.

***B. cylindrica*** Multiple flowers occur in groups of two or three and have a greenish-yellow, bulbous calyx with six to nine lobes that fold back against the upper calyx. Propagule narrow, with a rounded cylindrical appearance, no grooves or ribs.

***Rhizophora* species** *Rhizophora* has four calyx lobes, most have cork wart spots on leaf undersurfaces (note: *Bruguiera* species never have cork wart spots), and most Indo–West Pacific *Rhizophora* have prominent mucronate tips at their leaf apices (unlike *R. samoensis* in the southern Pacific islands, and the introduced *R. mangle*).

## GENETICS

### Variability of species

Some variation in calyx color of the flower occurs, with some trees having flowers described as crimson red, orange, yellowish red, creamy white, or green. Colors may also be mixed red and green, with their red sides often up-

**Left: Knee roots with rare instance of sprouting foliage stems. Gazi Bay, Kenya. Top right: Buttress roots and stem base, tree growing on man-made coral rubble platform. Yap, Federated States of Micronesia. Bottom right: Mature hypocotyls comparing a red "albino" form (above) and a normal dark-green form (below). Note also the color variation in calyces, red and red-green, which is independent of propagule color. Moreton Bay, Queensland, Australia.** PHOTOS: N.C. DUKE

per-most. Care must be taken to differentiate between calyx color and petal color, as this may at times be defined as flower color. Red coloration of the calyx is definitely more prevalent in sun-affected locations, within single trees and among trees.

### Known varieties

In NE Australia, *B. gymnorrhiza* has "albino" forms where some hypocotyls lack green pigment. These propagules are living, but they are non-viable, dying within a year of settlement after depleting reserves, because they cannot photosynthesize. When present, they are easily observed hanging alongside normal green hypocotyls from otherwise normal looking parent trees.

## ASSOCIATED PLANT SPECIES

Mangroves commonly occur in relatively distinct zones, which are controlled by factors such as salinity, tidal regime, soil type, and seed predators. Large-leafed mangrove is most commonly found in an intermediate location between the seaward edge of mangrove stands (often dominated by *Rhizophora* spp. and *Sonneratia alba*) and the landward edge, which may be dominated by a diverse mix of mangroves and mangrove associates.

### Associated species commonly found

Common associates on Pacific Islands include other mangrove tree species, especially *Rhizophora apiculata*, *R. samoensis*, *Sonneratia alba*, *Xylocarpus granatum*, *Heritiera littoralis*, *Ceriops tagal*, and *Lumnitzera littorea*. Other flora occasionally found with large-leafed mangrove include the mangrove fern (*Acrostichum aureum/speciosum*), nypa palm (*Nypa fruticans*), and a variety of vines (e.g., *Derris* spp.) and epiphytes (e.g., *Hydnophytum* spp.).

## ENVIRONMENTAL PREFERENCES AND TOLERANCES

### Climate

Large-leafed mangrove is a species of tropical and subtropical environments, which are characterized by moderately high and well distributed rainfall.

### Elevation range

0–2 m (0–6.6 ft), which is the elevation range between mean sea level and the highest tide.

### Mean annual rainfall

1000–8000 mm (40–315 in)

### Rainfall pattern

Grows in climates with a uniform rainfall pattern.

### Dry season duration (consecutive months with <40 mm [1.6 in] rainfall)

No specific information is known for large-leafed mangrove. Mangrove plants in general appear to depend on groundwater to sustain optimal growth, especially during drier months. Reduced growth in response to an El Niño event on Kosrae in 1997/1998 was presumably due to a decrease in freshwater input.

### Mean annual temperature

20–30°C (68–86°F) (estimate)

### Mean maximum temperature of hottest month

32–38°C (90–100°F) (estimate)

### Mean minimum temperature of coldest month

0–5°C (32–41°F) (estimate)

### Minimum temperature tolerated

-5°C (23°F) (estimate)

### Soils

Trees develop greatest stature and columnar growth form in estuaries of larger tropical rivers, characterized by fine clay and black mud sediments with relatively high levels of organic carbon. These soils are often anaerobic, with high concentrations of sulfide. However, these trees also occur at times in sites with more aerobic sediments consisting of fine sands to coarse stones and rocks. In these instances, knee roots are less prominent.

### Soil texture

Grows in light, medium, and heavy textured soils (sands, sandy loams, loams, sandy clay loams, clay loams, sandy clays, and clays).

### Soil drainage

Grows in soils with free and impeded drainage as well as waterlogged soils.

### Soil acidity

Acidic to neutral soils (pH 4.0–7.4).

### Special soil tolerances

Grows in saline soils. The optimal salinity range is reported to be 8–26 ppt (parts per thousand), compared with approximately 34–36 ppt for full-strength seawater.

### Tolerances

### Drought

The tree can tolerate drought periods reasonably well, although growth rate is reduced substantially.

## WHAT IS A MANGROVE?

Mangroves form a unique and dominant ecosystem comprised of inter-tidal marine plants, mostly trees, predominantly bordering margins of tropical coastlines around the world. These halophytic (salt tolerant) plants thrive in saline conditions and daily inundations between mean sea level and the highest tides, and they provide vital structure as habitat and food for similarly adapted resident and transient fauna. At low tide, mangrove plants exchange gases from exposed roots using special lenticels, while flooding tides allow uptake of nutrients and seed dispersal, often using especially buoyant propagules. The ecological limits defined by the diurnal tidal range explain the setting and why just 70 species around the world are called true mangroves (Tomlinson 1986, Duke et al. 1998), compared with adjacent rainforests that may have hundreds of tree species per hectare. Specialized morphological and physiological characteristics largely define and characterize mangrove plants, such as buttress trunks and roots providing support in soft sediments, above ground roots allowing vital gas exchange in anaerobic sediments, and physiological adaptations for excluding or expelling salt. Fewer than 22 plant families have developed such attributes, representing independent instances of co-evolution over millions of years to form today's mangrove habitats.

### Full sun

It grows well in full sun.

### Shade

Large-leafed mangrove is one of the most shade tolerant mangrove species. Seedlings may persist and grow under a full forest canopy (even less than 10% full sunlight).

### Fire

It has no tolerance of fire in close proximity.

### Frost

The tree is almost certainly not tolerant of sub-freezing temperatures for more than a few hours.

### Waterlogging

It can tolerate daily flooding up to depths of at least 1.5 m (5 ft) and even permanently saturated soils.

### Salt spray

The tree is highly tolerant of salt spray.

### Wind

It is not typically found on the extreme seaward (and most windswept) edges of mangrove forests. Planting in highly wind-prone locations is not recommended.

## Abilities

### Regenerate rapidly

Large-leafed mangrove regenerates effectively by natural dispersal and seedling establishment, but then tends to grow slowly, depending on freshwater inputs, muddy substrate, and nutrient availability.

### Self-prune

Self-prunes well in dense stands but maintains lower branches in more open-grown locations.

### Coppice

Does not coppice well but does respond much better to cutting and leaf removal than *Rhizophora* species, with sprouting along larger stems below leafy rosettes.

### Pollard

No reports were found of pollarding practices.

# GROWTH AND DEVELOPMENT

Growth rates vary with age. Growth in height is rapid shortly after establishment while food reserves are taken up from the hypocotyl. The rate then appears to slow in a sigmoid decline until the tree attains the maximum height obtainable on a particular site—the site maximal canopy height (Duke 2001). After this, trees tend to spread and broaden in canopy diameter rather than get taller.

## Growth rate

Large-leafed mangrove generally grows less than 1 m/yr (3.3 ft/yr) in height. Propagules planted in India averaged only 1.19 m (3.9 ft) tall after five growing seasons. Naturally regenerated saplings growing in small gaps on Kosrae have averaged about 10 cm/yr (4 in/yr) over a period of 6 years. Trees in some plantations on the Andamans have reportedly reached a height of 9–12 m (30–39 ft) and a circumference of 25–30 cm (10–12 in) in 15 years. Mean annual diameter increments of 0.17–0.21 cm (0.07–0.08 in) and 0.30 cm (0.12 in) have been reported for Malaysia and Bangladesh, respectively. In Micronesia, large-leafed mangrove growing on Pohnpei had diameter growth rates of 0.26 cm/yr (0.1 in/yr), and on Kosrae, 0.44 cm/yr (0.17 in/yr) (Cole et al. 1999).

A 100-year rotation was recommended for the Andaman Islands, at which time the "exploitable girth" should be around 70 cm (28 in).

## Flowering and fruiting

Flowering and "fruiting" occur continuously throughout the year, although distinctly seasonal peaks of hypocotyl production were reported for July–August in northern parts of the range and January–February in southern parts. Trees have notable and long periods of reproductive development, taking 1–2 years from first emergence of flower buds until maturation and drop of mature hypocotyls.

## Yields

No data available.

# PROPAGATION

Large-leafed mangrove is readily propagated by direct planting of propagules (viviparous seedlings). Although natural regeneration is generally relied upon around the Pacific region, this species is relatively easy to propagate artificially.

Propagation is simple and relies on the special feature of this genus: viviparous propagules. As such, planting simply entails gently pushing the distal end of the 10–15 cm (4–6 in) long hypocotyl one third of its length into the sediment, spaced at about 1 m (3.3 ft) intervals. No holes need to be dug, no nursery preparation, no stakes, and generally low

maintenance is required for growing seedlings in sheltered areas.

## Propagation by viviparous seedling

### Propagule collection

Propagules are available throughout much of the year, with peaks in July–August common in northern parts of the range and January–February in the southern parts. Mature propagules may be collected after they have fallen or directly off the trees. Only healthy looking propagules should be selected. Propagules that are shrunken or desiccated in appearance or that exhibit significant physical damage should be rejected. Although propagules with only minor borer damage may survive and grow, selection of propagules with no signs of borer or crab damage are strongly preferred. Propagules that already have some root or leaf development can be used in most cases but should not be stored for long.

### Propagule processing

No processing of mature propagules is required. They can be sown in nursery beds or planted in the field in the form in which they were collected.

### Propagule storage

Propagules can be kept viable for at least 6–7 days by storing them in brackish water or by wrapping them in wet burlap bags and storing them out of direct sunlight. It is likely that they can be kept even longer, but storage beyond 2 weeks is not recommended and long-term storage is not feasible.

### Propagule pretreatment

No pre-planting treatments are necessary.

### Growing area

Large-leafed mangrove can be grown in full sunlight or under a wide range of shade. In Australia, use of 30% shade for *Bruguiera* species is recommended.

### Seedling establishment

Leaves and roots may begin to develop within a week or two of sowing.

### Media

Although a wide variety of soil media are acceptable, a 50–50 mix of sand and peat has been recommended for Australian mangrove nurseries. Brackish water is recommended, but seedlings have also been successfully propagated using fresh water.

### Time to outplanting

Seedlings are ready for outplanting at the six-leaf (three-

**Planting mangroves on a storm-damaged site.** PHOTO: N. DUKE

node) stage if grown in nursery conditions. Older seedlings up to 0.5 m (20 in) tall have also been successfully transplanted. Planting may be undertaken at any time during the year. Direct propagule planting, will, however be restricted by their seasonal availability from parent trees, as they do not keep for extended periods unless planted out in pots.

### Guidelines for outplanting

Propagules or nursery-grown seedlings should have excellent survival on sites that have been properly selected and, if appropriate, protected from disturbance. Survival of 90% or greater is not unreasonable in such sites. On the other hand, survival may be zero on sites exposed to excessive wave action, inappropriate hydrologic or salinity regimes, or (rarely) disturbance by grazing animals (such as camels, goats, cattle, and horses).

## DISADVANTAGES

In general, large-leafed mangrove poses few significant disadvantages when planted in its native range. It is not especially susceptible to pests or pathogens and has not been reported to host major pests or pathogens of important crop species.

### Potential for invasiveness

Although the invasiveness of large-leafed mangrove has not been demonstrated, it is likely to be easily opportunistic due to its shade tolerance and its relatively wide range of tolerance for salinity and soil conditions. Other mangrove species introduced into Hawai'i have clearly demonstrated the general potential for invasiveness of mangroves in areas where they are not native and yet suitable growing conditions exist.

### Pests/pathogens

Susceptibility to pests and pathogens is believed to be low, with the exception of grapsid crabs and weevils, which frequently damage propagules and/or leaves.

### Host to crop pests/pathogens

No reports were found of large-leafed mangrove serving as the host for a known crop pest or pathogen.

## AGROFORESTRY/ENVIRONMENTAL PRACTICES

Large-leafed mangrove is probably of greatest value *in situ*, as this species (and mangroves as a whole) is believed to play a vital role in supporting marine food chains, protecting coastal areas, and improving water quality.

### Mulch/organic matter

Mangroves in general have relatively high productivity, including leaf and root production. Mangroves tend to create highly organic soil environments and also export organic matter to nearby marine environments. Large-leafed mangrove foliage may be relatively poor in quality compared to other mangroves such as *Sonneratia alba*, but it still is an effective producer and exporter of organic matter. Mulch in mangrove forests is hidden from view most of the time. If it were not for the small mangrove crabs, fallen leaves would be washed away with each tide. The crabs actively take leaves below ground, where they become underground mulch that can then become available to trees in the forest again.

### Soil stabilization

Mangroves in general are effective in stabilizing soils in intertidal areas. They may rapidly colonize newly formed mudflats and other areas of unstable soils within the intertidal zone. Although believed to be useful primarily for gas exchange, the knee roots of large-leafed mangrove may also help trap sediments.

### Windbreaks

Large-leafed mangrove has been planted in the Philippines to protect coastal homes from wind and wave action. Mangroves often occur adjacent to agricultural areas and may serve to protect crops from sea spray or storms.

### Woodlot

Mangroves adjacent to homes throughout the Pacific frequently serve as informal woodlots, particularly on islands with clear tenure systems that include mangrove areas, such as on Yap, in the Federated States of Micronesia.

### Native animal/bird food

Large-leafed mangrove is a largely unknown source of native animal foods. However, several observations demonstrate that the diversity and quantity of the source is likely to be extremely important in mangrove ecosystems. Numerous insects, crabs, and mollusks graze on green leaves in the forest canopy. Sesarmid crabs consume an unknown quantity of fallen leaves and propagules. Organic matter processed by these herbivores is believed to broadly support aquatic food chains in coastal regions. Birds notably feed and depend on floral nectaries of *Bruguiera* species. The relationship with birds is so well developed that this plant-animal relationship has co-evolved to create an unusual explosive pollen-release mechanism in *Bruguiera*

plants to disperse pollen to neighboring trees using bird visitors. Few mammals appear to use large-leafed mangrove as a major food source.

### Wildlife habitat

In addition to aquatic marine organisms (see Fish/marine food chain), mangroves serve as habitat for a wide range of terrestrial and arboreal wildlife. *Bruguiera* forests provide shelter and food for a number of associated fauna, including birds, small mammals, crustaceans, shellfish, and fish life. Fruit bats may roost in mangroves and are known to pollinate some species (although not large-leafed mangrove). In some cases, rare or endangered species have been documented to use large-leafed mangrove. An example is the nightingale reed-warbler (*Acrocephalus luscinia*), a U.S. federally listed endangered species, which has been found to nest in large-leafed mangrove trees on Saipan.

### Bee forage

*Bruguiera* species have limited nectar (largely consumed by birds), but they do have copious pollen that may be gathered by bees.

### Fish/marine food chain

Mangroves in general are believed to play a vitally important role in protecting and supporting marine food chains. Many fish species use mangroves during part of their life cycles, as do species of shrimp and crab. Species such as the mangrove crab (*Scylla serrata*) are common in mangroves with a high component of large-leafed mangrove, and are important sources of food and income on many islands in the region. Populations of some crab species may exceed 10/$m^2$ (1/$ft^2$) in parts of the Pacific. Senescent leaves having fallen from *Bruguiera* trees are taken by grapsid (small mangrove) crabs into their burrows. Buried leaves decompose and contribute to nutrient recycling in mangrove forests. Nutrients also feed directly and indirectly to associated estuarine and marine food chains. Mangrove areas with large-leafed mangrove may also serve as habitat for more "charismatic" marine megafauna, such as the saltwater crocodile.

### Coastal protection

Mangroves in general play an important role in protection of coastlines, fishponds, and other coastal infrastructure. Mangroves are planted explicitly for coastal or fishpond protection in some areas (e.g., parts of the Philippines) and there are laws in many locations aimed at protecting mangroves in large part because of this important function.

### Ornamental

Large-leafed mangrove is not widely used as an ornamental, although its dark green leaves, generally attractive form, and reddish-scarlet flowers do make it an attractive tree. Packaged plants (sprouting hypocotyls) are sold in the Okinawan Islands (Japan) as an ornamental plant at tourist shops.

## USES AND PRODUCTS

In terms of direct use by people, the most widespread use of large-leafed mangrove is for wood, which is used for purposes ranging from firewood to construction of homes and canoe parts. Other uses of the tree include food (mainly from the propagules), dyes, and medicines.

### Staple food

Leaves and peeled propagules have reportedly been soaked, boiled, and eaten as a staple in Papua New Guinea, although most likely only in times of severe shortage of other foods. Although large-leafed mangrove is not widely used for food, reports of the use of propagules as a food source also exist for India, Bangladesh, and other parts of Southeast Asia.

### Fruit

The fruit (propagule) is reportedly "eaten cooked, after scraping or grating, washing, and drying (to remove tannins) and sometimes mixed with coconut in Melanesia and Nauru; fruit is sold as a vegetable at the Honiara Market [Solomon Islands]." (Clarke and Thaman 1993)

### Medicinal

The bark is used as an abortifacient and for treating burns in the Solomon Islands The bark is reportedly used for diarrhea and fever in Indonesia. The astringent (and mildly toxic) bark has also been used to treat malaria in Cambodia. The fruits have antiviral properties, and bark extracts of the closely related *B. sexangula* are reportedly active against at least two types of cancerous tumors (Sarcoma 180 and Lewis lung carcinoma).

### Timber

The wood is widely used for structural components (e.g., poles, beams, and rafters) of traditional homes and other structures. It is also used for other purposes, ranging from traditional uses such as fishing stakes, spears, and copra-huskers to use as a source of chips for pulp production. The species has also been used for transmission and telephone poles in some regions (e.g., the Andaman Islands), and is likely durable in direct contact with the ground (i.e., rot resistant).

## THE LEGEND OF THE ORIGIN OF POHNPEI

Long ago, there lived a man named Sapkini on the island of Eir. Under his guidance, a great canoe was built to sail into the unknown in search of a new land. Sapkini believed this new land existed where the sky touched the sea. Sapkini wisely selected his crew, each of whom was endowed with the skills or magical power needed for sailing or working the land. After many days at sea they met an octopus named Lidakika, who directed them to a distant shallow reef on which a small coral head was exposed. They named it Tierensapw ("bit of land"), because it was no larger than the distance between the canoe and its outrigger. From this bit of coral, the island of Pohnpei was built.

By magic, they called stones and boulders to Tierensapw from other places, but the earth and soil was continuously washed away by the waves of the sea. The people called on Katengenior ("stabilizer of the shore") for help. Katengenior surrounded the land and created a barrier reef for protection. Still the land was not stable, so they called on Katenanik, who caused the mangrove trees to take root to hold the shore in place. After the shore was secure, the people dug earth and piled it into a platform, which they named pei (stone altar). Pohnpei was built on top of (pohn) the altar, thus the island was named Pohnpei, or "upon a stone altar."

Source: Lambeth 2000

### Fuelwood

The wood has a high calorific value and is used for fuelwood on some Pacific Islands (e.g., Kosrae). It is also made into charcoal in countries such as Malaysia and Indonesia.

### Craft wood/tools

Sometimes used for tool handles or digging sticks.

### Canoe/boat/raft making

The wood has been used to make canoe parts. In the Marshall Islands, it has been used for keel-pieces (maal), outrigger (kie), and outrigger struts (kein-eon erre). Canoe paddles are also made from large-leafed mangrove on some islands.

### Body ornamentation/garlands

Flowers of the closely related *B. sexangula* are used in Hawai'i to produce a type of lei called the kukuna o ka la ("rays of the sun") (Allen 1998).

### Tannin/dye

Used to produce dyes ranging from red-brown to black (the latter with repeated dying). The bark has a high tannin content, but tends to color leather excessively unless the bark is collected "at the end of each growing season."

### Cosmetic/soap/perfume

The knee roots (or "breathing roots") reportedly have been used for making perfumes.

## COMMERCIAL CULTIVATION

Although not as desirable as *Rhizophora* species, large-leafed mangrove is frequently sold by commercial firewood suppliers on some islands (e.g., Kosrae, Chuuk in FSM). *Bruguiera* timber is harvested commercially for charcoal production in SE Asia, although *Rhizophora* is preferred. The calorific value of the timber is enhanced significantly by converting it to charcoal. Mangrove forests are used for wood chips in Malaysia, New Guinea, and the Solomons using unsustainable harvesting of native forests. Large-leafed mangrove plantations have been established on Fiji for land reclamation and timber.

### Spacing

Mangrove plantations in general are typically planted at spacings of about 1.0 to 1.5 m (3.3–5 ft). Spacings wider than about 2.5 m (8 ft) tend to result in a high proportion of multiple stemmed and/or shorter trees. Wider spacings may be desired for coastal protection projects but not for timber production.

In the absence of significant natural mortality, timber plantations should be thinned to densities of 2.5 to 3.5 m (8–11.5 ft) as the stand develops and becomes crowded.

### Management objectives

In areas where the mangrove fern (*Acrostichum aureum*) is common, it may need to be controlled to promote early growth of large-leafed mangrove, although the high shade tolerance of this species may make this less important than for other mangrove tree species.

Some published guidelines for mangrove silviculture exist and are referenced in this profile, but guidelines on thinning, fertilizing, etc., that are specific to large-leafed mangrove are generally unavailable.

### Growing in polycultures

Large-leafed mangrove naturally occurs in mixed-species stands, and each species has its own ecological and economic values. Mixed-species plantings are therefore rec-

ommended, including *R. apiculata* and other *Rhizophora* species.

Large-leafed mangrove may be slower growing than other mangrove species but is able to persist and may even eventually dominate in mixed-species plantations.

### Estimated yields

No data available.

### Markets

Markets on most Pacific Islands are local in nature, with little in the way of large-leafed mangrove products (other than indirect products like mangrove crabs and fruit bats) being exported from one island to another. In Southeast Asia, large quantities of large-leafed mangrove wood chips and charcoal may be moved greater distances and in greater volumes than wood products on smaller islands.

## PUBLIC ASSISTANCE AND AGROFORESTRY EXTENSION

USDA Forest Service
Institute of Pacific Islands Forestry
1151 Punchbowl Street, Room 323
Honolulu, HI 96813, USA
Attn: Tropical Forested Wetlands Team

Marine Botany Group
Centre for Marine Studies
The University of Queensland
St. Lucia QLD 4072, Australia
Web: http://www.marine.uq.edu.au/marbot/index.htm

Extension offices for agroforestry and forestry in the Pacific: http://www.traditionaltree.org/extension.html

## INTERNET

For a nice set of FAQ's about mangroves (from the Phil-

**Mature forest showing stems and typical above ground roots with Erick Waguk (Kosraen State Forester) pictured for scale. Kosrae, Federated States of Micronesia.** PHOTO: N.C. DUKE

ippines: http://www.pemsea.org/young%20environ/ye101/mangrove_index.htm

For a brief summary of *B. gymnorrhiza* characteristics produced by the Purdue University Center for New Crops & Plant Products: http://newcrop.hort.purdue.edu/newcrop/duke_energy/Bruguiera_gymnorrhiza.html

For a useful publication called "One Hundred Pacific Island Agroforestry Species": http://www.unu.edu/unupress/unupbooks/80824e/80824Eop.htm

## BIBLIOGRAPHY

**(☛ indicates recommended reading)**


Allen, J.A. 1998. Mangroves as alien species: the case of Hawaii. Global Ecology and Biogeography Letters 7: 61–71.

Allen, J.A. 2002. *Rhizophora mangle* L. In: Vozzo, J.A. (ed.). Tropical Tree Seed Manual. Agriculture Handbook 721. USDA Forest Service, Washington, DC.

Allen, J.A., Krauss, K.W., Duke, N.C., Herbst, D.R., Bjorkman, and O. Shih. 2000. *Bruguiera* species in Hawaii: systematic considerations and ecological implications. Pacific Science 54(4): 331–343.

Bandaranayake, W.M. 1995. Survey of mangrove plants from Northern Australia for phytochemical constituents and UV-absorbing compounds. Current Topics in Phytochemistry 14: 69–78.

Bandaranayake, W.M. 1998. Traditional and medicinal uses of mangroves. Mangroves and Salt Marshes 2: 133–148.

Bandaranayake, W.M. 1999. Economic, traditional and medicinal uses of mangroves. Australian Institute of Marine Science, AIMS Report #28, Townsville, Australia.

Clarke, A., and L. Johns. 2002. Mangrove nurseries: construction, propagation and planting. Fish Habitat Guidelines FHG 004. Department of Primary Industries, Queensland Fisheries Service. <http://www.dpi.qld.gov.au/fishweb/10802.html>.

Clarke, W.C., and R.R. Thaman. 1993. Agroforestry in the Pacific Islands: Systems for Sustainability. United Nations University Press, Tokyo.

Cole, T.G., K.C. Ewel, and N.N. Devoe. 1999. Structure of mangrove trees and forest in Micronesia. Forest Ecology and Management 117: 95–109.

Dahdouh-Guebas, F., L.P. Jayatissa, D. Di Nitto, J.O. Bosire, D. Lo Seen, and N. Koedam, 2005. How effective were mangroves as a defence against the recent tsunami? Current Biology 15(12): 443–447.

☛ De Lacerda, L.D. 2002. Mangrove Ecosystems: Function and Management. Springer-Verlag, Berlin, Germany.

Ding Hou. 1958. Rhizophoraceae. pp. 428–493. In: van Steenis, C.G.G.J. (ed.). Flora Malesiana, Vol. 5. Noordhoff-Kolff N.V., Djakarta, Indonesia.

Ding, H. 1958. *Bruguiera*. Flora Malesiana Vol. Ser. I 5(4): 457–468.

Duke, N.C. 1992. Mangrove floristics and biogeography. Tropical Mangrove Ecosystems. In: Robertson, A.I. and D.M. Alongi. American Geophysical Union, Washington, DC.

Duke, N.C. 1999. The 1998 survey of *Rhizophora* species in Micronesia. Report to the USDA Forest Service. Marine Botany Group, Botany Department, The University of Queensland, Brisbane, Australia.

Duke, N.C. 2001. Gap creation and regenerative processes driving diversity and structure of mangrove ecosystems. Wetlands Ecology and Management 9: 257–269.

Duke, N.C., and Z.S. Pinzón. 1992. Aging *Rhizophora* seedlings from leaf scar nodes: a technique for studying recruitment and growth in mangrove forests. Biotropica 24(2a): 173–186.

Duke, N.C., J.S. Bunt, and W.T. Williams. 1984. Observations on the floral and vegetative phenologies of northeastern Australian mangroves. Australian Journal of Botany 32: 87–99.

Duke, N.C., M.C. Ball, and J.C. Ellison. 1998. Factors influencing biodiversity and distributional gradients in mangroves. Global Ecology and Biogeography Letters 7: 27–47.

Durant, C.C.L. 1941. The growth of mangrove species in Malaya. Malayan Forester 10: 3–15.

Ellison, J.C. 1995. Systematics and distributions of Pacific Island mangroves. In: Maragos, J.E., M.N.A. Peterson, L.G. Eldredge, J.E. Bardach, and H.F. Takeuchi (eds.). Marine and Coastal Biodiversity in the Tropical Island Pacific Region. Vol. 1. Pacific Forum, Pacific Science Association, East-West Center, Honolulu.

Ellison, J.C. 1999. Present status of Pacific Island mangroves. pp. 3–19. In: Eldredge, L.G., J.E. Maragos, and P.L. Holthus (eds.). Marine/Coastal Biodiversity in the Tropical Island Pacific Region: Population, Development and Conservation Priorities. Volume II. Pacific Science Association/East West Center Honolulu.

Ge, X.-J., and N.C. Duke. 2004. A mangrove hybrid, *Bruguiera* × *rhynchopetala* (Rhizophoraceae) from China and NE Australia. Australian Journal of Botany (in press).

☛ Hogarth, P.J. 1999. The Biology of Mangroves. Oxford University Press, New York.

Ko, W.C. 1978. Taxa nova Rhizophoracearum. Acta Phytotaxon Sin 16: 109–110.

Krauss, K.W., and J.A. Allen. 2003. Factors influencing the regeneration of the mangrove *Bruguiera gymnorrhiza* (L.) Lamk. on a tropical Pacific island. Forest Ecology and Management 176: 49–60.

Lambeth. L. 2000. An Assessment of the Role of Women in Fisheries in Pohnpei, Federated States of Micronesia. Secretariat of the Pacific Community, Noumea, New

Caledonia. <http://www.spc.int/coastfish/Sections/Community/english/publications/pohnpei.pdf>
Macnae, W. 1968. A general account of the flora and fauna of mangrove swamps in the Indo-Pacific region. Advances in Marine Biology 6: 73–270.
Marco, H.F. 1935. Systematic anatomy of the woods of the Rhizophoraceae. Tropical Woods 44: 1–20.
McCusker, A. 1984. Rhizophoraceae. 22: 1–10. In: A.S. George (ed.). Flora of Australia. Bureau of Flora and Fauna, Australian Government, Canberra.
☛ Robertson, A.I., and D.M. Alongi (eds.). 1992. Tropical Mangrove Ecosystems. American Geophysical Union, Washington, DC.
☛ Saenger, P. 2002. Mangrove Ecology, Silviculture and Conservation. Kluwer Academic Publishers, Boston.
☛ Tomlinson, P.B. 1986. The Botany of Mangroves. Cambridge University Press, Cambridge, UK.
Walsh, G.E. 1977. Exploitation of mangal. pp. 347–262. In: Chapman, V.J. (ed.). Ecosystems of the World: Wet Coastal Ecosystems. Elsevier Science Publishing Company, Amsterdam.
Watson, J.G. 1928. Mangrove forests of the Malay peninsula. Malayan Forest Records 6. Fraser & Neave, Singapore.
Wilkinson, K.M., and C.R. Elevitch. 2003. Propagation protocol for production of container *Bruguiera gymnorrhiza* (L.) Savigny plants. In: Native Plant Network. University of Idaho, College of Natural Resources, Forest Research Nursery, Moscow, Idaho. <http://www.nativeplantnetwork.org>.
Wyatt-Smith, J. 1953. The Malayan species of *Bruguiera*. Malay Forestry 16: 156–161.
Wyatt-Smith, J. 1960. Field key to the trees of mangrove forest in Malaya. Malay Forester 23: 126–132.




# *Bruguiera gymnorrhiza* (large-leafed mangrove)

**Authors:** James A. Allen[1] and Norman C. Duke[2]

1. Paul Smith's College, PO Box 265, Paul Smiths, New York 12970, USA. Web: http://www.paulsmiths.edu
2. Marine Botany Group, Centre for Marine Studies, The University of Queensland, St. Lucia QLD 4072, Australia; http://www.marine.uq.edu.au/marbot/index.htm

**Acknowledgments:** The authors and publisher thank Tom Cole, Farid Dahdouh-Guebas, Judith Drexler, Dale Evans, and Kathy Ewel for their input.

**Recommended citation:** Allen, J.A., and N.C. Duke. 2006. *Bruguiera gymnorrhiza* (large-leafed mangrove), ver. 2.1. In: Elevitch, C.R. (ed.). Species Profiles for Pacific Island Agroforestry. Permanent Agriculture Resources (PAR), Hōlualoa, Hawai'i. <http://www.traditionaltree.org>.

**Sponsors:** Publication was made possible by generous support of the United States Department of Agriculture Western Region Sustainable Agriculture Research and Education (USDA-WSARE) Program; SPC/GTZ Pacific-German Regional Forestry Project; USDA Natural Resources Conservation Service (USDA NRCS); State of Hawai'i Department of Land & Natural Resources Division of Forestry & Wildlife; and the USDA Forest Service Forest Lands Enhancement Program. This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, and Agricultural Experiment Station, Utah State University, under Cooperative Agreement 2002-47001-01327.

**Series editor:** Craig R. Elevitch

**Publisher:** Permanent Agriculture Resources (PAR), PO Box 428, Hōlualoa, Hawai'i 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129; E-mail: par@agroforestry.net; Web: <http://www.agroforestry.net>. This institution is an equal opportunity provider.