## Mangrove plants

Mangrove plants are mostly trees and large shrubs, but also include ferns and a palm species. In the Atlas, a total of 73 species and hybrids are considered to be true mangroves: all have adapted to mangrove environments and are rarely, if ever, found elsewhere. Thirty-eight of these species might be considered 'core species' that typify mangroves and dominate in most locations. The remainder are rarely so abundant or are more typically found on the fringes of mangrove habitats (Table 1).

### Table 1 Core mangrove species

| **Indo-West Pacific** | | | |
|---|---|---|---|
| **Family** | **Species** | **Family** | **Species** |
| Avicenniaceae | *Avicennia alba* | Rhizophoraceae (cont.) | *Ceriops australis* |
| | *Avicennia integra* | | *Ceriops decandra* |
| | *Avicennia marina* | | *Ceriops tagal* |
| | *Avicennia officinalis* | | *Kandelia candel* |
| | *Avicennia rumphiana* | | *Kandelia obovata* |
| Combretaceae | *Lumnitzera littorea* | | *Rhizophora apiculata* |
| | *Lumnitzera racemosa* | | *Rhizophora mucronata* |
| | | | *Rhizophora samoensis* |
| Meliaceae | *Xylocarpus granatum* | | *Rhizophora stylosa* |
| | *Xylocarpus moluccensis* | Sonneratiaceae | *Sonneratia alba* |
| Rhizophoraceae | *Bruguiera cylindrica* | | *Sonneratia apetala* |
| | *Bruguiera exaristata* | | *Sonneratia caseolaris* |
| | *Bruguiera gymnorhiza* | | *Sonneratia griffithii* |
| | *Bruguiera hainesii* | | *Sonneratia lanceolata* |
| | *Bruguiera parviflora* | | *Sonneratia ovata* |
| | *Bruguiera sexangula* | | |
| **Atlantic East Pacific** | | | |
| **Family** | **Species** | **Family** | **Species** |
| Avicenniaceae | *Avicennia bicolor* | Pellicieraceae | *Pelliciera rhizophorae* |
| | *Avicennia germinans* | Rhizophoraceae | *Rhizophora mangle* |
| | *Avicennia schaueriana* | | *Rhizophora racemosa* |
| Combretaceae | *Conocarpus erectus* | | |
| | *Laguncularia racemosa* | | |

**Note:** See Atlas for a list of all 73 mangrove species and hybrids.

The environment in which mangroves grow is harsh, with variable but often high salinity; regular inundation; and with soft, waterlogged and often unstable sediments. To survive, most mangrove plants have developed adaptive strategies in morphology, physiology and/or reproduction. These include:

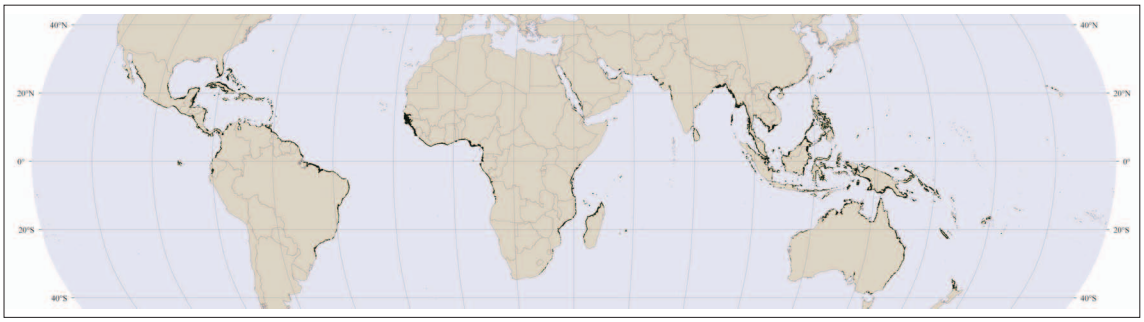
- Coping with salinity through ultra-filtration at the root endodermis, deposition in bark and roots, disposal through leaf senescence, and secretion via salt glands.
- The development of aerating roots such as stilt roots, pneumatophores, knee roots and buttress roots, which provide important structural support and aid the supply of oxygen to the roots.
- The formation of lenticels in aerial roots to facilitate gaseous exchange.
- The development of vivipary, in which young plants begin to grow within fruits while they are still attached to the parent plant, enabling more rapid establishment and early growth when they settle in the right environment. Vivipary is best developed in species of Rhizophoraceae: the embryo grows out of the seed and then out of the fruit while still attached to the parent plant, so that the propagule that is eventually released is a seedling rather than a seed.

Roots need air and in the waterlogged soils of mangrove forests this can be in short supply. Mangrove species have developed a range of root formations that allow access to the open air at low tide, including the knee roots of *Bruguiera* spp. *Photo: M. Kainuma.*

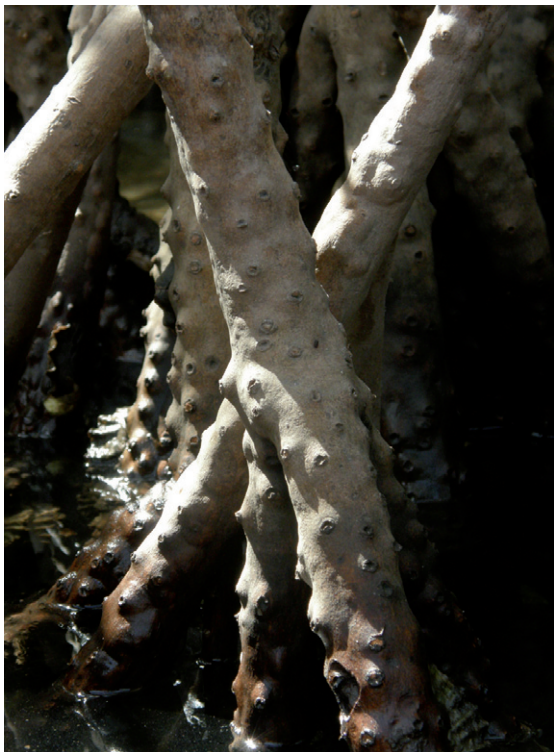
## Mangrove environment

The habitats formed by mangroves are variously termed forests, swamps and communities. The intertidal zone in which mangroves grow is restricted spatially, bound as it is by the sea on one side and terrestrial environments (where competition for space with other plants is fierce) on the other. Aridity and high salinity often further restrict growing space. Although adapted to salinity, mangroves thrive in areas where seawater is diluted by high regular rainfall, groundwater flows or rivers.

## Figure 1 Global distribution of mangroves



Where conditions are conducive—typically in deltas, estuaries and coastal lagoons in wetter regions—mangroves form extensive forests, where canopy height may reach 30 m or more. At the other extreme, where conditions are arid or saline, fewer species can survive and trees grow only in dwarf or scrub formations. Mangroves are widely found along open coastlines in places where wave energy is sufficiently low and suitable sediments occur.



Lenticels, shown here on the aerial roots of a *Rhizophora* sp. are small pores that allow gaseous exchange in air but are blocked when the root is submerged. *Photo: M. Spalding*

### *Mangrove forest morphology*

**Fringing mangroves are relatively narrow strips tracing shorelines, lagoons or the more steeply shelving part of estuarine or deltaic channels.**

**Basin mangroves are broader formations, typically occurring in very shallow depressions away from the water's edge. There is no wave action and the mangroves may be inundated only infrequently.**

**Over-wash mangroves are patches, islands or small promontories that are entirely covered by water at high tides and have little leaf litter accumulation.**

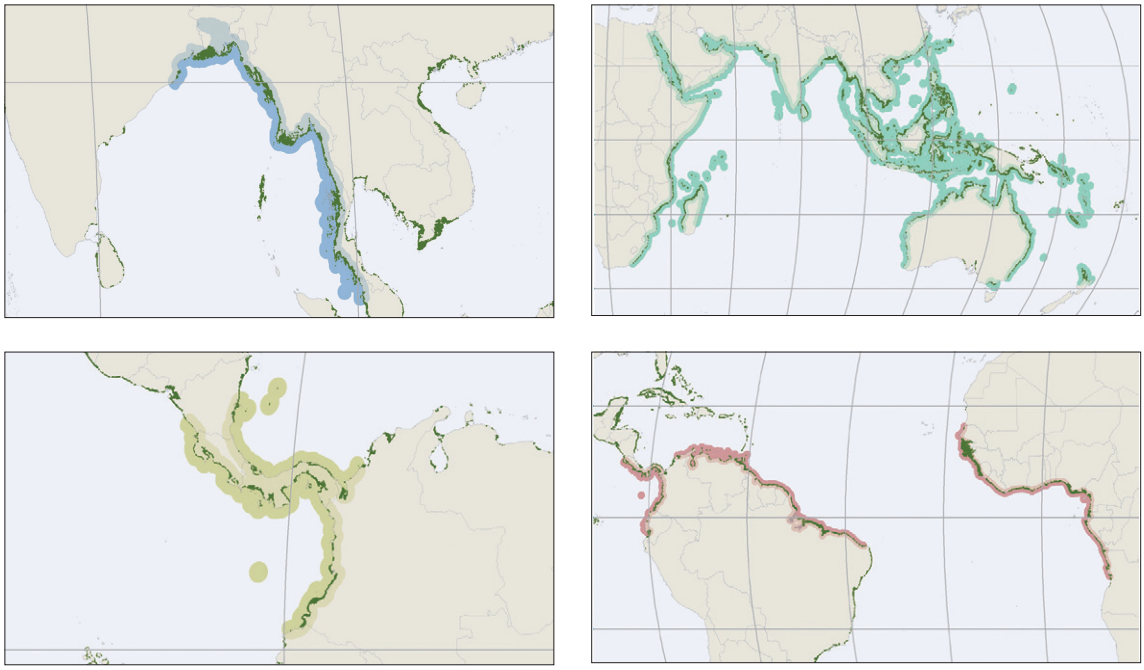
## Mangrove distribution

The Atlas includes a new global map derived almost entirely from satellite imagery captured between 1999 and 2003. According to this map, the global mangrove area is 152 360 km², the most accurate estimate ever compiled.[2] Mangroves are found in 123 countries and territories. Despite this broad spread, over two-thirds of the world's mangroves are found in just twelve countries, with Indonesia alone accounting for over 20%.

Figure 1 shows the global distribution of mangroves and their predominantly tropical range. The largest areas are found on the wetter coastlines of South and Central America and West and Central Africa, and from northeast India through Southeast Asia to northern Australia. Although mangroves are still widespread in more arid regions,

2 *Shortly after the 2010 release of the World Atlas of Mangroves, Giri et al. (2010) published an alternative estimate of mangrove area of 137 760 km² (in 118 countries in 2000), also derived from recent satellite imagery. The difference between the two estimates is relatively minor. The authors of the World Atlas of Mangroves have been unable to see the underlying data for the Giri et al. study but point out that it was an unsupervised classification with no ground-truthing. The data generated for the World Atlas of Mangroves, on the other hand, were partially supervised, and some of the large national datasets were fully supervised (ie, the anlaysts had a prior knowledge of the existence of mangroves in the areas being mapped). The World Atlas of Mangroves also involved an extensive review process, with comments and corrections to the maps provided by national and regional experts including some ground-truthing. While it would be valuable to compare the two global maps and perhaps combine them, the authors of the World Atlas of Mangroves are confident that the data in the World Atlas of Mangroves constitute the most reliable global assessment.*

**Figure 2 Different mangrove species have remarkably different ranges: e.g. *Heritiera fomes* (top left), *Avicennia marina* (top right), *Pelliciera rhizophorae* (bottom left) and *Rhizophora racemosa* (bottom right)**



including subtropical and southern Australia, South Asia, the Middle East and parts of East Africa, the total area in these regions is limited and they are typically dominated by sparse formations (Table 2).

The largest individual tracts of mangroves occur on wet deltaic coasts, where they often extend inland for several tens of kilometres and where mature forests often contain large trees and forest canopies over 20 m in height. The best known of these is the Sundarbans, a vast mangrove forest that straddles the boundary between India and Bangladesh; it covers an area of 6500 km² and extends 85 km inland.

**Table 2 Summaries of mangrove areas**

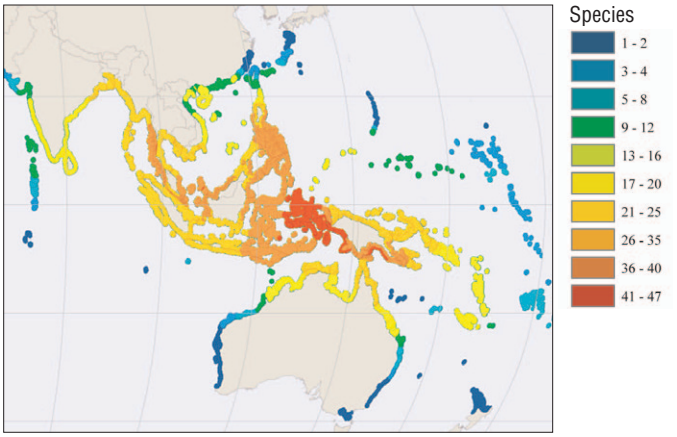
| Region | Area (km²) | Proportion of global total |
|---|---|---|
| East Africa | 7917 | 5.2% |
| Middle East | 624 | 0.4% |
| South Asia | 10 344 | 6.8% |
| Southeast Asia | 51 049 | 33.5% |
| East Asia | 215 | 0.1% |
| Australasia | 10 171 | 6.7% |
| Pacific Ocean | 5717 | 3.8% |
| North and Central America | 22 402 | 14.7% |
| South America | 23 882 | 15.7% |
| West and Central Africa | 20 040 | 13.2% |
| **Total** | **152 361** | |

## Biogeographic patterns

The Atlas presents the first-ever global compilation of range maps for individual mangrove species, compiled with expert input and support from the International Union for Conservation of Nature (IUCN). These maps show the considerable variation in ranges of different species, as illustrated in Figure 2. By combining the range maps of individual species the Atlas vividly illustrates patterns of mangrove diversity.

The global centre of mangrove biodiversity is in South and Southeast Asia (Figure 3), while there are also diversity centres in the western Indian Ocean and around southern Central America. Diversity decreases away from the tropics.

**Figure 3 Asian mangrove diversity**



Two distinct floristic realms of mangrove distribution are widely recognized. One is the Indo-West Pacific realm, or eastern group, which extends east from eastern Africa to the islands of the central Pacific. The other is the Atlantic East Pacific realm, or western group, which includes the Americas and West and Central Africa. There is virtually no overlap in species between these realms, with the exception of the fern *Acrostichum aureum*.

The fern *Acrostichum aureum* is found in both the Indo-West Pacific and Atlantic East Pacific regions. *Photo: Chan Hung Tuck*

The Indo-West Pacific floristic realm comprises 62 unique species and hybrids, most of them overlapping with or restricted to a centre of mangrove diversity that extends west of northern Australia and New Guinea through Southeast Asia to the Bay of Bengal. In contrast, the Atlantic East Pacific realm has only twelve species and hybrids, four of which are restricted to the coasts of Central America and Colombia.

The two mangrove realms can be further subdivided into seven subregions: West America; East America; West and Central Africa; East Africa; Indo-Andaman; Southeast Asia; and Australasia.

## Mangrove ecology

Mangrove forests are complex ecosystems. Many show patterns of zonation, with different parts of the forest dominated by different species due to variations in the ability of species to cope with salinity, aridity, inundation and sediments. The dynamic nature of coastal environments also means that many forests show a temporal succession, with pioneer species helping to stabilize soils and capture sediments before being replaced by other species.

Under ideal conditions, mangroves are among the world's most productive ecosystems, with typical net primary productivity rates for 10-metre-high forests in the order of 9 tonnes per hectare per year, and considerably higher rates for high-canopy forests. There is considerable interaction—through the movement of species, the supply of nutrients and the modification of environments—between mangroves and other coastal ecosystems such as salt marshes, salt pans, swamp forests, tidal freshwater forests, mud flats, sea grasses and coral reefs (see box for definitions of typical coastal ecosystems).

### Coastal ecosystems

**Salt marshes** are saline wetlands dominated by herbs, grasses and low shrubs. While they predominate and are sometimes considered functionally equivalent to mangroves in temperate regions, they also grow around mangroves in many tropical areas, often surviving in areas of high salinity but in some places also forming pioneer vegetation on new sediments.

**Salt pans** are areas in the upper tidal zone where aridity and salinity are so high that few plants can survive.

**Mud flats** are wide, level areas of intertidal soft muddy sediments that typically extend seawards from below the mid-tide level. They are usually devoid of vegetation but are often nutrient-rich and host both algae and numerous burrowing filter-feeders.

**Coral reefs** are large physical structures built and maintained by the growth of stony corals and other associated species. They often act as breakwaters and provide calm lagoons to landward, enabling mangroves to grow in their lee. They are highly sensitive to sediments and so are not found in some areas where mangroves are abundant. Many reef fish use mangroves as nursery areas.

**Swamp forests**. The transition to terrestrial vegetation at the upper reaches of mangrove forests can be through saltmarsh or salt-pan communities, but in some areas there is a more subtle change in forest type. This may include a gradation to seasonally or occasionally flooded swamp forest and to tidal freshwater forest.