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1. Introduction

Mangroves are a common and important feature of the sand flats, river banks and coastlines of the tropics and subtropics of the world. They exist at the interface of two environments: land and sea.

The most luxuriant and diverse mangals are found in the humid tropical regions of the world (Macnae 1968). The present distribution of mangroves suggests that the region between Malaysia and northern Australia was the major centre of mangrove flora evolution (Ding Hou 1958, 1972; Specht 1981). On the fossil evidence, Specht (1981) postulated that the centre of the origin of mangroves is more likely to have been the region from south-western and northern Australia to Papua New Guinea rather than the Malaysian Archipelago.

The present mangrove flora in Australia is one of the richest in the world. Twenty-seven species were classed as mangroves by Beadle (1981), while some 39 species of mangroves were recognised by Duke (1992). Approximately half of the world's mangrove species have been identified in Australia.

Many ecological studies have been conducted on mangroves in Australia from a geomorphological and vegetational perspective including Macnae (1966; 1968), Saenger et al. (1977), Clough (1982) and Robertson and Alongi (1992). However, with the exception of Bridgewater (1985), no studies have attempted phytosociological analyses of these regions.

In this paper, we will discuss some aspects of mangrove vegetation, such as the phytosociological communities in Australia and the biogeographical distribution of mangrove species in East Asia and Australia.

2. Distribution of mangroves in Australia

Mangroves in Australia are found around most of the mainland coast, except for the southern coastline of Western Australia. They are not found in Tasmania. In Western Australia the southern limit is 33°16'S and in eastern Australia it is Corner Inlet, Wilson's Promontory, Victoria, at 38°45'S. The largest number of mangrove species occurs on the northern and north-eastern coastline. The number of mangrove species declines rapidly with increasing latitude. Lower water and air temperatures as well as the predominance of

winter rainfall effectively prevent the southward extension of many species (Hutchings and Saenger 1987).

The southernmost mangroves in the world are a monospecific stand of *Avicennia marina*, found in Australia at 38°45'S. Similarly, on the eastern coast of New Zealand, mangroves reach their natural southern limit in the Kutarere arm of Ohiwa Harbour at 38°00'S (Crisp, Daniel and Tortell 1990).

3. Distribution of mangroves in Japan (East Asia)

Figure 1 shows the distribution of mangroves in Japan. The northern limits of mangrove genera in East Asia are at Kiire (31°22'N), Kyushu in Japan and on the north-eastern part of the Fujian seashore (approximately 26°N) in China. Monospecific *Kandelia candel* was recorded at both sites. The most diverse areas in Japan are on Iriomote Island (southern end of Japan) where 10 species have been recorded: *Kandelia candel, Avicennia marina, Sonneratia alba, Rhizophora stylosa, Bruguiera gymnorrhiza, Lumnitzera racemosa, Heritiera littoralis, Excoecaria agallocha, Nypa fruticans* and *Acrostichum aureum* (Suzuki 1979, 1981; Miyawaki, Suzuki et al. 1982).

According to Peng (1987), 31 species of mangrove belonging to 20 genera have been recorded in China and 7 species in Fujian Province (23-25°N): *Kandelia candel, Avicennia marina, Aegiceras corniculatum, Acanthus ilicifolius, Bruguiera gymnorrhiza, Excoecaria agallocha* and *Hibiscus tiliaceus*. *Hibiscus tiliaceus* is not always included as a mangrove species but as a mangrove associate.

4. Phytosociological study of mangrove vegetation in Australia

This is a preliminary report on a phytosociological study of mangroves in Australia. The purpose of the study was to collect and analyse phytosociological data on mangrove stands on the eastern coast of Australia. The phytosociological investigations were carried out in field surveys in Queensland and New South Wales in Australia during 1995 (Figure 2). The phytosociological study sites ranged from Mossman (16°25'S) in north-eastern Queensland to Newcastle (32°52'S) on the central coast of New South Wales.

4.1 Phytosociological method

The vegetation was studied in accordance with the concepts and methods of the Zürich-Montepellier School (Braun-Blanquet 1964, Miyawaki and Suzuki 1980). It was determined that each selected stand had to cover a minimum survey space in a habitat which showed homogeneous physiognomy. Thus, the stands were even. All of the species within each stand were checked to make a complete species list by layer. Multistructural communities such as *Rhizophora* forests were divided into three or four layers according to the stands; tree (tree-1 and tree-2), shrub and herb layers. The Braun-Blanquet method was employed to determine the cover class (cover degree-abundance scale) and sociability of the species in each layer.

The cover degree-abundance scale is that originally proposed by Braun-Blanquet in 1964.

5 any number of individuals covering more than 3/4 of the area

4 any number of individuals covering 1/2 to 3/4 of the area
3 any number of individuals covering 1/4 to 1/2 of the area
2 great abundance of individuals or covering at least 1/20 of the area
1 plentiful but of small cover value
+ sparsely or very sparsely present, covering a very small or insignificant area

Another quantitative estimate per species is the sociability rating. The sociability scale is that originally proposed by Braun-Blanquet in 1964.

5 growing in very extensive patches or covering the sample area in one large population
4 growing in large groups or colonies, forming patchy carpets, fairly extensive
3 growing in small patches, troops, cushions
2 growing in small groups or tufts or clumps
1 growing singly (the foliage of one plant does not touch another)

The data of releves collected in the field surveys were collated into a raw data table which was then rearranged into a differential table. Finally, the vegetation types were classified into communities by taking into account all of the data available.

4.2 Plant communities in eastern Australia

The phytosociological data collected during the field surveys were classified into communities. As a preliminary result of the investigation in eastern Australia, it was possible to recognise 17 types of plant communities.

4.2.1 *Avicennia marina* community

Location: Fullerton Cove, Newcastle, NSW (Table 2, Nos 1-10)
Iluka, NSW (Table 3, No. 1)
Yeppoon, Qld (Table 6, No. 1)

The *Avicennia marina* community was differentiated by monospecific *Avicennia marina*. There are usually no associated species. The data for this community were collected from 12 survey points in Newcastle, Iluka and Yeppoon. The community had a height of 2-13 m and a cover of 30-95%. The community is a pioneer or outer fringe mangrove vegetation in northern Australia and is a typical form on the southern coasts of Australia.

Avicennia marina is common in Australian mangroves and is widely distributed to the southern limits. *Avicennia marina* is tolerant of a very wide salinity range, which appears to account for its sporadic distribution from the outer seaward margin in some areas to the inner landward fringe in others, and even in hypersaline patches where the plants are stunted or shrubby (Macnae 1968, Beadle 1981).

4.2.2 *Aegiceras corniculatum-Avicennia marina* community

Location: Kooragang, Newcastle, NSW (Tab. 1, Nos 1-4 and Tab. 3, Nos 1-6)
Iluka, NSW (Table 4, Nos 2-4)

Mobbs Bay, Ballina, NSW (Table 5, Nos 1-5)
Yeppoon, Qld (Table 6, Nos 3, 4, 6)
Keppel Bay, Qld (Table 6, Nos 2, 5)

The *Aegiceras corniculatum-Avicennia marina* community, which was investigated at 13 survey points, is a two-layered community with *Avicennia* trees and *Aegiceras* shrubs. The surveyed areas were in Iluka and Ballina, NSW, and Yeppoon and Keppel Bay, Queensland. The community had a height of 3-11 m and a cover of 40-95%. Total number of species ranged from 2-5.

The community was widely distributed and often occupied considerable areas on the coasts of southern Queensland and New South Wales. Some of the *Avicennia marina* community pioneered the *Aegiceras corniculatum-Avicennia marina* community.

4.2.3 *Aegiceras corniculatum* community

Location: Kooragang, Newcastle, NSW (Table 3, Nos 7-8)
Iluka, NSW (Table 4, No. 5)

The *Aegiceras corniculatum* community was a common shrub vegetation which was dominated and characterised by *Aegiceras corniculatum*. The *Aegiceras corniculatum* community was found on the front or margin of the *Aegiceras corniculatum-Avicennia marina* community. *Aegiceras corniculatum* often grew together to form a thicket up to 4 m tall. The data for this community were collected at Kooragang, Newcastle and in Iluka, NSW. The community at Kooragang was composed of the dominant *Aegiceras corniculatum* (3.5-4 m high) and occasional *Avicennia marina* (5-8 m high). The community at Iluka was an *Aegicera* shrub together with salt-marsh herbaceous species: *Sesuvium portulacastrum* and *Suaeda australis*.

4.2.4 *Avicennia marina-Excoecaria agallocha* community

Location: Mobbs Bay, Ballina, NSW (Table 5, No. 6)

The data of the *Avicennia marina-Excoecaria agallocha* community were collected at Mobbs Bay, NSW. The *Avicennia marina-Excoecaria agallocha* community was a 6 m high forest with *Excoecaria agallocha* and *Avicennia marina*. The total number of species was five. Some of the component species were introduced from adjacent communities because the area of the community was not large. *Excoecaria agallocha* is mainly distributed on the landward edge of the mangroves.

4.2.5 *Aegialitis annulata-Avicennia marina* community

Location: Yeppoon, Qld (Table 6, Nos 7-8, 10-11)
Keppel Bay, Qld (Table 6, No. 9)
Karumba, Qld (Table 11, Nos 1-5)

The *Aegialitis annulata-Avicennia marina* community was found at Yeppoon, Keppel Bay and Karumba, Queensland. The *Aegialitis annulata-Avicennia marina* community was a two-layered community with tall *Avicennia* trees and small *Aegialitis* shrubs. The

ecological structure of the community was the same as the *Aegiceras corniculatum-Avicennia marina* community. The community had a 4-7 m high shrub layer and a 0.5-1.2 m high herb layer. The shrub layer had a cover of 40-95% and the herb layer had a cover of 5-70%. *Aegialitis annulata*, called the club mangrove, grows to about 1.5-2 m in height and the base of the trunk is thickened making the plant look bottom-heavy and club-like.

4.2.6 *Ceriops tagal* community

Location: Keppel Bay, Qld (Table 7, No. 1)
Gladstone, Qld (Table 7, Nos 2-6)

The *Ceriops tagal* community was found at Keppel Bay and Gladstone, Queensland. The community was from 3 to 6.5 m high, had a cover of 40-95% and a total number of species of 1-2. The dominant species of the community was *Ceriops tagal.* The community was found towards the landward edge of mangrove vegetation. The areas of the community developed as a line 3-6 m wide along the river or coast and were not large at all. *Ceriops tagal* grew to 7-8 m high in the areas having some freshwater influence but often occurred as short, stunted trees in saline environments.

4.2.7 *Ceriops tagal-Lumnitzera racemosa* community

Location: Gladstone, Qld (Table 8, Nos 1-2)
Yeppoon, Qld (Table 8, No. 3)
Keppel Bay, Qld (Table 8, Nos 4-5)

The data for the *Ceriops tagal-Lumnitzera racemosa* community were collected at Gladstone, Yeppoon and Keppel Bay in Queensland. The community was characterised by the dominant *Lumnitzera racemosa* and the common *Ceriops tagal*, which was from 2.5 to 5 m high and covered 70-95%. The total number of species varied from 2 to 3. *Lumnitzera racemosa,* called black mangrove, usually does not have above-ground roots. The southern limit of the distribution of the species is in Moreton Bay in southern Queensland.

4.2.8 *Bruguiera exaristata-Ceriops tagal* community

Location: Keppel Bay, Qld (Table 7, Nos 7-8)

The data for this community were collected at Keppel Bay, Queensland. The community was characterised and differentiated by *Bruguiera exaristata* and *Ceriops tagal*, and had a height of 5 m and a cover of 80-90%. Total number of species was 2-3. The community was distributed on the inland side of the mangrove area. *Bruguiera exaristata* had smaller propagules with green caps and is distributed only on the northern coasts of Australia from Gladstone northwards.

4.2.9 *Lumnitzera racemosa-Excoecaria agallocha* community

Location: Keppel Bay, Qld (Table 8, No. 6)

The *Lumnitzera racemosa-Excoecaria agallocha* community was 8 m high and was dominated by *Lumnitzera racemosa* and *Excoecaria agallocha*. The data were collected on Keppel Bay, Queensland. The habitat of the community was on the most inland side of the mangroves at Keppel Bay. *Excoecaria agallocha*, called milky mangrove, can grow up to 15 m tall.

4.2.10 *Rhizophora stylosa* community

Location: Gladstone, Qld (Table 9, Nos 1-2)
Keppel Bay, Qld (Table 9, No. 3)

The *Rhizophora stylosa* community was 4-5 m high, covered 95% and was composed of *Rhizophora stylosa* only. The data for this community were collected at Gladstone and Keppel Bay, Queensland. Total number of species of the community was 1-2. The community was a *Rhizophora*-dominated mangrove forest typical of the southern coast of Australia.

4.2.11 *Osbornia octodonta-Rhizophora stylosa* community

Location: Cape Ferguson, Qld (Table 10, Nos 1-3)

The *Osbornia octodonta-Rhizophora stylosa* community was from 5 to 7 m high, and the total number of species varied from 3 to 6. The community was characterised by dominating *Rhizophora stylosa* and 2-3 m high shrubs of *Osbornia octodonta. Osbornia octodonta* belongs to the same family as the *Eucalyptus* (Myrtaceae) with its crushed leaves having the same distinctive smell.

4.2.12 *Osbornia octodonta-Avicennia marina* community

Location: Cape Ferguson, Qld (Table 10, No. 4)

The *Osbornia octodonta-Avicennia marina* community was a 7 m high forest dominated by *Avicennia marina* with *Osbornia octodonta* shrubs. The data for the community were collected at Cape Ferguson, Qld. The community was typical of *Avicennia marina*-dominated forests in northern Australia.

4.2.13 *Lumnitzera racemosa* community

Location: Cape Ferguson, Qld (Table 10, No. 5)

The *Lumnitzera racemosa* community, dominated by *Lumnitzera racemosa*, occurs on the inland side of the mangrove areas. The data for the community were collected at Cape Ferguson, Qld. The community had a height of 2 m and a cover of 30%. The habitat of the *Lumnitzera racemosa* trees was similar to that of *Excoecaria agallocha* and *Ceriops tagal*. Sometimes, these three species form mixed stands.

4.2.14 *Rhizophora stylosa-Rhizophora apiculata* community

Location: Cairns, Qld (Table 12, Nos 1-4)

The *Rhizophora stylosa-Rhizophora apiculata* community comprised a tall tree vegetation, having a height of 15-21 m and a cover of 70-95%. The community was dominated and characterised by two *Rhizophora* species: *Rhizophora apiculata* and *Rhizophora stylosa*. The total number of species was from 2 to 3 and the cover of shrub and herb layers was less than 20%. *Rhizophora* species were trees with stilt- or prop-type above-ground roots.

4.2.15 *Rhizophora stylosa-Ceriops parviflora* community

Location: Cairns, Qld (Table 12, Nos 5-6)

The *Rhizophora stylosa-Bruguiera parviflora* community was 8 m high and the total number of species was from 4 to 5. The data for this community were collected in Cairns, Qld.

4.2.16 *Avicennia marina-Sonneratia alba* community

Location: Cairns, Qld (Table 12, No. 7)

The data for the *Avicennia marina-Sonneratia alba* community were collected at Cairns. The community had a height of 7 m and a cover of 95% in tree layer and 40% in shrub and herb layer. Total number of species was three and *Sonneratia alba* was the dominant species. The habitat was on the river-side front of the mangroves near Cairns Airport.

4.2.17 *Bruguiera gymnorrhiza-Bruguiera parviflora* community

Location: Mossman, Qld (Table 13, No. 1)

The *Bruguiera gymnorrhiza-Bruguiera parviflora* community comprised a tall tree vegetation, having a height of 22 m and a cover of 90%. The community was dominated and characterised by two *Bruguiera* species: *Bruguiera gymnorrhiza* and *Bruguiera parviflora*. The total number of species was three and the cover of tree 2 and shrub layers was 10%. *Bruguiera* species have buttresses at the base of the trunk and knee roots. They can grow to 25 m tall.

5. Latitudinal limits in Australia and East Asia (Japan)

Approximately 40 mangrove species, belonging to 14-15 families, occur in Australia. None of the species are endemic. The flora as a whole is related to the mangrove flora of South-East Asia, with most of the genera and some of the species extending to the east coast of Africa and the Red Sea (Beadle 1981). *Osbornia octodonta* is listed as endemic to Australia by Macnae (1966) but (very rarely) occurs as far north as the Philippines. The biogeographic distribution of mangrove species in Australia has been described by Lear and Turner (1977), Saenger et al. (1977), Semeniuk et al. (1978, Western Australia), Wells (1983) and Hutchings and Saenger (1987). The limits are proceeded by a gradual attenuation of species with increasing latitudes, with the largest number of species occurring on the northern and north-eastern coastlines, where most of the 39 (Duke 1992)

mangrove species are recorded. This concentration can be attributed to the high temperature and rainfall of the tropical climate.

The latitudinal limits of mangroves in Australia and East Asia are as follows:

Western Australia	Southern limit: 33°16'S
Eastern Australia	Southern limit: 38°45'S
East Asia (Japan)	Northern limit: 31°21'N
East Asia (China)	Northern limit: c. 26°N

The *Kandelia candel* community in the Zhejiang Province (27°31'N) of China is the northernmost mangrove but it was transplanted in 1958 (Peng 1987).

Mangrove vegetation grows in a particular kind of rather unstable, difficult environment. Walsh (1974) identified five characteristics as essential mangrove prerequisites on a global scale, and Chapman (1975, 1977) added two others. They are (1) air temperature within a certain range, (2) mud substrate, (3) protection, (4) salt water, (5) tidal range, (6) ocean current and (7) shallow shores. Saenger and Moverley (1985) suggested that, in the presence of an adequate rainfall, temperature is the major factor in reducing species abundance with latitude.

5.1 Distribution of mangroves and mean temperature

Walsh (1974) and Chapman (1975, 1977) maintained that extensive mangrove development occurs only when the average air temperature of the coldest month is higher than 20°C and where the seasonal range does not exceed 10 degrees. Also, the distribution of mangroves appears to correlate reasonably well with the 16°C isotherm for the mean temperature of the coldest month (Chapman 1977). However, Barth (1981) maintained that the presence of mangroves correlates with those areas where the water temperature of the warmest month exceeds 24°C, and the limits occur in those waters that never exceed 24°C throughout the year.

Avicennia marina grows in the Abrolhos Islands off Western Australia and Barwon Heads, Port Phillip Bay, Westernport Bay and Corner Inlet in Victoria, where the daily mean minimum temperature drops to 4°C and 7°C in July (Melbourne and Adelaide respectively), and where minimum temperatures of 0°C have been recorded (Macnae 1966). Hutchings and Saenger (1987) stated that, once established, *Avicennia* can withstand low but not sub-zero temperatures. The occurrence of mangrove fossils in south-western Australia (Churchill 1973) suggests that the current mangrove vegetation on the southern Australian coastline is a relict of earlier warmer conditions which has managed to maintain itself in a few favourable localities.

In Japan, there are quite similar mean temperatures in the five locations: Kagoshima (Kiire), Muroto, Ashizuri and Shiono (Table 14, Figure 1). However, there is no mangrove vegetation, except in Kagoshima (Kiire). This suggests that *Kandelia candel* in Kiire may be a relict from an earlier time or may have been transplanted from the southern islands more than a few hundred years ago.

Kiire, Kagoshima, the northern limit of Japanese mangroves, is located at 31° North. Newcastle, Sydney, Melbourne and Wilsons Promontory in south-eastern Australia are all located more than 32° South. Japan has higher mean temperatures than south-eastern Australia during the summer months (June-September in Japan and December-March in Australia) but south-eastern Australia has higher mean temperatures during the winter (December-March in Japan and June-September in Australia). Therefore, one of the factors limiting mangrove distribution may well be the temperature during winter.

6. Biodiversity of mangrove species:

Latitudinal comparison of distribution of mangrove species

Figure 2 shows the latitudinal distribution of the main mangrove species in Australia and East Asia. The upper two lines of each species show data from the east and west coasts of Australia. The lower two lines show data from China and Japan. For example, *Avicennia marina* develops up until 33-36°S (in detail 33.00 to 36.59°S) on the west coast of Australia, 37-40° South on the east coast of Australia, and up until 29-32° North in China and Taiwan and 26-28° North in Japan.

Some biogeographic characteristics were identified from the data collected: (1) Most mangrove species developed in both areas having similar longitude. (2) Many mangrove species in the southern hemisphere developed at higher latitudes than in the northern hemisphere. (3) Only a few mangrove species such as *Acanthus ebracteatus* and *Nypa fruticans* developed at higher latitudes in the northern hemisphere than in the southern hemisphere. (4) The east coast of Australia was richer in species than the west coast. Most of the main mangrove species developed to a more southerly latitude on the east coat of Australia than on the east coast. *Avicennia marina, Excoecaria agallocha, Rhizophora stylosa* and *Lumnitzera racemosa* are examples. (5) *Kandelia candel*, which developed in both South-East and East Asia, is not distributed in Australia. (6) *Osbornia octodonta, Bruguiera exaristata, Xylocarpus australasicus* etc., which occur in Australia, are not found in East Asia. However, *Osbornia octodonta* is occurs in the Philippines.

These ecological or biogeographical characteristics may be result of topographical and geographical factors and human activities. Most of the coastal areas in China were developed in earlier times and have become artificial coastlines without mangroves or other vegetation. Except for Kiire in Kyushu, mangroves in Japan developed only in the small southern islands. The isolation of the mangrove vegetation on the small islands in the south might have limited its expansion to areas farther north.

7. List and classification of mangrove vegetation in Australia and Japan

Many studies of mangrove vegetation in Japan are already available and can provide important background information. Table 15 shows the list of the Japanese mangrove vegetation which has been reported from a phytosociological viewpoint. Phytosociological data list of Japan for each type of mangrove community, that is each dominant species, and each publication (table 15) is listed together with the investigated areas (location name) with latitudinal and longitudinal data, the names of communities, height and cover of vegetation, total number of component species, primary and secondary dominant species, their cover degrees and their sociabilities.

Mangrove vegetation in Japan were categorised by dominant species as the following 8 types of vegetation:

(a) *Kandelia candel*-dominated vegetation (Height of vegetation: 1-6 m)
(b) *Bruguiera gymnorrhiza*-dominated vegetation (Height of Vegetation: 1.5-10 m)
(c) *Sonneratia alba*-dominated vegetation Height of vegetation: 2-8 m)
(d) *Rhizophora stylosa*-dominated vegetation (Height of vegetation: 2.8-7 m)
(e) *Avicennia marina*-dominated vegetation (Height of vegetation: 1-2.5 m)
(f) *Lumnitzera racemosa*-dominated vegetation (Height of vegetation: 2-5 m)
(g) *Myporum bontioides*-dominated vegetation (Height of vegetation: 1.3-2 m)
(h) *Excoecaria agallocha*-dominated vegetation (Height of vegetation: 3-4 m)

Except for Bridgewater (1985), phytosociological studies of mangrove vegetation in Australia have not previously been done. In this paper, Australian mangrove vegetation has been listed using data from Bridgewater (1985), Saenger (1983) and Saenger (1995, unpublished) as well as original data (tables 1-13). However, the phytosociological data lists (Tables 1-13, 16) do not cover all over community types of Australian mangroves. This paper is the first report of a series of phytosociological studies on Australian mangrove vegetation. Phytosociological data list of Australia for each type of mangrove community, that is each dominant species, and each publication (table 16) is listed together with the investigated areas (location name) with latitudinal and longitudinal data, the names of communities, height and cover of vegetation, total number of component species, primary and secondary dominant species, and their cover degrees.

Mangrove vegetation in Australia were categorised by dominant species as the following 14 types of vegetation:

(a) *Kandelia candel*-dominated vegetation (Height of vegetation: 0.5-14 m)
(b) *Ceriops tagal*-dominated vegetation (Height of vegetation: 0.9-6.5 m)
(c) *Rhizophora stylosa*-dominated vegetation (Height of vegetation: 2.6-21 m)
(d) *Excoecaria agallocha*-dominated vegetation (Height of vegetation: 5-9 m)
(e) *Sonneratia alba*-dominated vegetation (Height of vegetation: 5.8-8.1 m)
(f) *Xylocarpus australasicus*-dominated vegetation
(g) *Lumnitzera racemosa*-dominated vegetation (Height of vegetation: 2-4.5 m)
(h) *Bruguiera exaristata*-dominated vegetation (Height ????)
(i) *Camptostemon schultzii*-dominated vegetation (Height ?????)
(j) *Rhizophora lamarcki*-dominated vegetation (Height of vegetation: 4.4-5.3 m)
(k) *Aegiceras corniculatum*-dominated vegetation (Height of vegetation: 1.5-8 m)
(l) *Aegialitis annulata*-dominated vegetation (Height of vegetation: 0.6-0.8 m)
(m) *Bruguiera parviflora*-dominated vegetation (Height of vegetation: 22 m)
(n) *Bruguiera parviflora*-dominated vegetation (Height of vegetation: 8 m)

8. Discussion

In this paper, original phytosociological data from 80 stands in New South Wales and Queensland, Australia, have been reported. The number of stands researched was not enough to analyse and classify Australian mangrove vegetation from a phytosociological viewpoint. However, the preliminary analysis, using the original and other data, indicates

that Australian mangrove vegetation could be categorised into the same types of phytosociological communities as those of Japan and South-East Asia.

Australian mangrove vegetation originally developed in relation to neighbouring areas such as New Guinea, New Zealand, and South-East and East Asia. Most of the component species were common to both Australia and East Asia. However, the distribution areas and the biodiversity in Australia are richer than in the equivalent latitudes of East Asia. Detailed phytosociological studies of mangroves in Australia might be important and useful in the analysis and classification of mangrove vegetation in South-East and East Asia.

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10. References

Barth, H. 1981. The Biogeography of Mangroves. In: Sen, D.N. and K.S. Rajpurohit (eds). Contributions to the Ecology of halophytes. Vol. 2, Tasks for Vegetation Science, pp. 66-131. The Hague: Dr W. Junk.

Beadle, N.C.W. 1981. The Vegetation of Australia. 690 pp. Cambridge University Press.

Chapman, V.J. 1975. Mangrove Biogeography. In: Walsh, G.E., S.C. Snedaker and H.J. Teas (eds). Proceedings of the International Symposium on Biology and Management of Mangroves, Vol. 1, pp. 3-22. Gainesville Univ. Florida.

Chapman, V.J. 1977. Introduction. In Ecosystems of the World. I. Wet Coastal Ecosystems, pp. 1-29. Amsterdam: Elsevier.

Churchill, D.M. 1973. The Ecological Significance of Tropical Mangroves in the Early Tertiary Floras of Southern Australia. Geol. Soc. Aust. Publ. 4: 79-86.

Clough, B.F. (ed.) 1982. Mangrove Ecosystems in Australia. Australian National University Press. Canberra.

Crisp, P., L. Daniel and P. Tortell. 1990. Mangroves in New Zealand: Trees in the Tide. 69 pp. CP Books.

Ding Hou. 1958, 1972. Rhizophoraceae. Flora of Malaysiana (Ser. I), 5: 429-293, 6: 965-967.

Duke, N.C. 1992. Mangrove Floristics and Biogeography. In: Robertson, A.I. and Alongi, D.M. (eds). Tropical Mangrove Ecosystems. Coastal and Estuarine Studies 41. American Geophysical Union, Washington, DC. pp. 63-100.

Hutchings, P. and P. Saenger. 1987. Ecology of Mangroves. 388 pp. University of Queensland Press.

Lear, R. and T. Turner. 1977. Mangroves of Australia. 84 pp. University of Queensland Press.

Macnae, W. 1966. Mangroves in eastern and southern Australia. Aust. J. Bot. 14: 67-104.

Macnae, W. 1968. A General Account of the Fauna and Flora of Mangrove Swamps and Forests in the Indo-West-Pacific Region. Adv. Mar. Biol. 6: 73-270.

Miyawaki, A., K. Suzuki, S. Suzuki, Y. Nakamura et al. 1982. Phytosociological Studies of Mangrove Vegetation in Japan. 1. Mangrove Vegetation in Iriomote Island. Bull. Inst. Envir. Sci. Techn. Yokohama Natn. Univ. 9: 77-89.

Peng, L. 1987. The Mangrove Ecosystem in China, In C.D. Field and A.J. Dartnall (eds): Mangrove Ecosystems of Asia and the Pacific, Proc. of Research for Development Seminar, Townsville, Australia, 1985, pp. 40-52. Australian Institute of Marine Science.

Saenger, P., and J. Moverley. 1985. Vegetative phenology of mangroves along the Queensland coastline. Proc. Ecol. Soc. Aust. 13:257-65.

Saenger, P., R.L. Specht, M.M. Specht and V.J. Chapman, 1977. Mangal and Coastal Salt-marsh Communities in Australia. In: Ecosystems of the World. I. Wet Coastal Ecosystem (ed. V.J. Chapman), pp. 293-345. Elsevier, Amsterdam.

Saenger, P. 1983. Mangrove of Adelaide and Duck Creek, Bowen.(Unpubl. Research Report)

Semeniuk, V., K.F. Kenneally and P.G. Wilson. 1978. Mangroves of West Australia. Western Australian Naturalists' Clus, Perth. 80 pp.
Specht, R.L. 1981. Biography of Halophytic Angiosperms (saltmarsh, mangrove and seagrass). In: Keast, A. (ed.) Ecological Biogeography of Australia. pp. 577-589. The Hague: Dr W. Junk.
Suzuki, K. 1979. Vegetation of the Ryukyu Islands. Bull. Inst. Envir. Sci. Techn. Yokohama Natn. Univ. 5 (1): 87-150.
Suzuki, K. 1981. Salt-marsh and Mangroves. In: Miyawaki, A. (ed.). Vegetation of Japan. Vol. 2, Kyushu. pp. 27-33. Shibundo. Tokyo.
Walsh, G.E. 1974. Mangroves: A Review. In: Reinhold, R.J. and W.H. Queen (eds) Ecology of Halophytes. pp. 51-174. N.Y. Academic Press.
Wells, A.G. 1983. Distribution of mangrove species in Australia. In *Tasks for vegetation science,* ed. H.J. Teas, vol. 8, pp. 57-76. The Hague: Dr W. Junk.

Map 1. Distribution of mangroves in Japan.

Map 2. Location map of the phytosociological survey sites in Australia (see Tables 1-13).

APPENDIX 2

PHYTOSOCIOLOGICAL DATA OF AUSTRALIA FOR EACH DOMINANT SPECIES, EACH STUDY LOCATION AND EACH PUBLICATION

LEGEND:

No. of ID

Latitude

Longitude

Location

Community

1st: primary dominant species and cover degree

2nd: secondary dominant species and cover degree

3rd: tertiary dominant species and cover degree

No. of releve(s)

Height of Vegetation

Cover of Vegetation

No. of species

Source

APPENDIX 1

PHYTOSOCIOLOGICAL DATA OF JAPAN FOR EACH DOMINANT SPECIES, EACH STUDY LOCATION AND EACH PUBLICATION

LEGEND:

No. of ID

Latitude

Longitude

Location

Community

1st: primary dominant species and cover degree/sociability degree

2nd: secondary dominant species and cover degree/sociability degree

3rd: tertiary dominant species and cover degree/sociability degree

No. of releve(s)

Height of Vegetation

Cover of Vegetation

No. of species

Source