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CHAPTER 6

VEGETATION AND FLORA OF THE COCOS (KEELING) ISLANDS

BY

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ABSTRACT

The vegetation and plant species occurring on the 22 vegetated Cocos (Keeling) islands have been classified numerically based on sample plots for the large islands as well as from checklists developed for each island from extensive reconnaissance. The vascular flora of about 130 species comprises approximately 50% native species, but there are no endemic species described. Most of the 69 introduced species are to be found on the larger settled islands and only one of these species has spread to the smaller islands. The relationship between island area and indigenous species richness shows a close fit to a power relationship. The more remote island of North Keeling has a distinct species composition compared to similar-sized islands of the main atoll.

The pre-settlement vegetation has been extensively modified for coconut plantations, except for certain parts of North Keeling, where tall *Pisonia grandis* - *Cocos nucifera* forest occurs with small amounts of *Cordia subcordata* and other species. These forests are fringed on the lagoon shore by *Pemphis acidula* tall shrubland and on the exposed ocean shores by *Argusia argentea* shrubland. Each of these communities support breeding colonies of seabirds. On the main atoll, remnant vegetation occurs most commonly along the strand and in some places appears to be relatively recent. Many species on the Cocos (Keeling) atolls are restricted in their distribution there. In some cases these represent relict distributions, whilst a few could be considered to be pioneer populations.

INTRODUCTION

The Australian external Territory of the Cocos (Keeling) Islands is situated in the north-eastern Indian ocean at 12°S, 96°E, is 2400 km north-west of North West Cape on the Australian mainland and 960 km south-west from Java. The Territory consists of two coral atolls about 25 km apart with a maximum ground elevation of 9 m above mean sea level. The smaller, northern atoll, is known locally and historically as Keeling Island and was inhabited intermittently and on a seasonal basis between *ca.* 1830 and 1929 (Gibson-Hill 1948). The main atoll, which continues to be known by various names and is here referred to as the Cocos atoll, consists of 21 vegetated islands, some of which have been

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inhabited since 1827 and all of which have been extensively cleared for coconut plantations. Keeling Island (North Keeling), on the other hand, has retained more natural vegetation and is still a major seabird rookery for at least six species (Stokes *et al.* 1984).

As the only atolls in the eastern Indian Ocean, and being relatively recently settled, these islands are of considerable scientific interest, but their isolation has prevented intensive scientific study. A series of naturalists have visited, the most notable being Charles Darwin for 11 days in 1836 (Darwin 1845); H.O. Forbes for 22 days in 1879 (Forbes 1879, 1885); H.B. Guppy for 5 months in 1888 (Guppy 1889); F. Wood-Jones for a year in 1905 (Wood-Jones 1912); and C.A. Gibson-Hill for 11 months in 1941 (Gibson-Hill 1950). Gibson-Hill (1948) presented the only systematic account of the vegetation in the form of a description of dominants and a sketch map of the plant communities of Keeling Island. Major plant collections have been made by C. Darwin (Henslow 1838), H.O. Forbes, F. Wood-Jones (1912), H.B Guppy (1889), I. Telford (1985) and the author in 1986-7.

The Cocos (Keeling) Islands lie on an isolated spur of the submarine Ninety-East Ridge and are formed on a volcanic base rising from a depth of 5,000 m, with an unknown thickness of coral over the base (Jongsma 1976). Large solution and/or collapse dolines up to 20 m deep cover the south-eastern bed of the Cocos lagoon and possibly indicate a considerable depth of underlying limestone. Most of the islands are developed from coral sand, shingle and rubble deposits over a breccia platform that is just above mean sea level (Woodroffe *et al.* 1990) and beach rock commonly outcrops on the more exposed sandy shores.

The highest elevations occur on the south and east ocean shores where sand and shingle deposits rise briefly to a maximum of 9 m forming a single elongate coastal dune best developed along the entire length of Pulu Atas as a sand dune and on North Keeling as a shingle ridge. Apart from these dunes, most of the islands are less than 3 m above sea level. The most leeward island of the Cocos atoll (Pulu Luar) displays a more complex geomorphology, being a mature moat island (Stoddart & Steers 1977) with a small saltwater lagoon. Jacobson (1976) studied the freshwater lens on Pulu Selma (Home Island) and concluded that the minimum width of island to sustain an exploitable Ghyben-Herzberg lens was 400 m. However during the present study in April and May 1986, fresh water was observed in wells on islands down to 100 m width (see Falkland 1988). The only naturally occurring surface freshwater is at the seasonal swamp known as Bechet Besar on the north-east shore of Pulu Panjang (West Island). On Pulu Luar (Horsburgh Island) there is a seasonal groundwater swamp identified by a ground layer of *Mariscus javanicus*.

Meteorological records for various periods and locations on the Cocos atoll are available as a composite record from 1902, at least for rainfall. The annual average rainfall for the period 1902-1982 was 1994 mm with a range from 1099 mm to 3288 mm and a median of 1969 mm. Mean monthly rainfall varies from 81 mm in October to 256 mm in April, with the dry season extending from September to December. Temperatures and humidities vary little throughout the year with an absolute annual temperature range from 21°C to 31°C. The wind régime is one of predominantly south-east trades for over 300 days per annum. Wind direction frequency analysis show south-easterly winds dominating from December to March whilst for the rest of the year there is a strong easterly component as well. Cyclone frequency within a five degree cell is about 0.25 in the region. Cyclones have passed near enough to the main atoll to cause damage in 1862, 1876, 1893, 1902, 1909, 1944, 1968, 1973 and 1988.

The purpose of the present survey was to establish the present composition of the flora on an island basis and to analyze the floristic and vegetation patterns of the entire Territory. The delineation of communities, relict stands and rare species distributions will serve as a basis for land use planning, the establishment of conservation priorities and the development of management aims.

METHODS

Circular sample plots of radius 10 m were located on the six largest islands (Keeling, Luar, Tikus, Selma, Atas, Panjang) along transects selected to maximize the detection of vegetation and floristic change along environmental gradients (Gillison & Brewer 1986). The major environmental gradients considered in the layout of the transects were:-

- ocean strand to lagoon strand;
- potential for a freshwater lens; and
- ocean coastline aspect.

Transects were oriented at right angles to the ocean coastline (Fig. 2) and sample plots were positioned on both strandlines (ocean/reef and lagoon) and at 60 m intervals along the transect; unless there was a change in the height or composition of the top stratum, in which case additional plots were selected. In each plot, plant species present were recorded, as well as litter depth, soil surface texture and canopy height and dominants.

All vegetated islands were surveyed (Pulu Pasir supports only occasional sprouting coconuts and was not included). For consistency, the Cocos-Malay names for the islands have been used throughout. Several islands have two Malay names apparently related to their origin from separate islands. In this report, Pulu Selma includes Pulu Gangsa (joined by human intervention) and Pulu Cepelok includes Pulu Wak-Banka, apparently joined by storm deposits before settlement in 1825. During the course of systematic collecting on the islands, the presence of each species on each island was recorded as well as an overall estimate of the species abundance on the island. A six-point ordinal abundance scale from very rare (less than 10 plants sighted) through rare, occasional, frequent, common to abundant was used. A complete set of voucher specimens is deposited at the Australian National Botanic Gardens (CBG) and nomenclature follows the *Flora of Australia* (1993).

The floristic and quantitative data were primarily analyzed using the Pattern Analysis Package (PATN, Belbin 1992) at the C.S.I.R.O. Division of Water and Land Resources. The dissimilarity coefficient used for sites was the Bray-Curtis measure or the Kulczynski coefficient and the two-step procedure (Austin & Belbin 1981) was used for the between-species dissimilarity. Cluster analysis was hierarchical agglomeration using UPGMA fusion with ß set to -0.1 to minimize space distortion (Belbin 1992).

Vegetation patterns were also derived from panchromatic aerial photographs taken in 1976 at a scale of 1:44,400 (R.A.A.F. Film No. 8737) and 1987 colour photography at 1:10,000 (A.S.O. Film SOC760). Interpretation was done using a Zeiss Interpretoscope and transferred to a base map using a Zoom Transfer Scope. Island areas were measured off the R.A.S.C. Series R811 Cocos Island Sheet Special (1:25,000).

RESULTS

THE FLORA

Exclusive of plants found only in cultivation the total vascular species count for these islands is 130 (Appendix 1). Given the variation in sampling intensity by past collectors (Table 1), it is difficult to be certain which species are introduced, except by examination of their biology, biogeography and present-day distribution as well as the historical record. Species found only in heavily disturbed areas and often on one or two large islands only, have usually been regarded as introduced in this analysis, and these account for about 50% of the flora (Table 2). Most of these species are pantropical herbs (Table 2) found on Pulu Panjang and many were probably introduced since the airfield was built on Pulu Panjang in 1944.

The vast majority of the native species are Indo-Pacific strand plants that are predominantly sea-dispersed. There are no endemic species described at this stage, save for the variety *cocosensis* of *Pandanus tectorius* (Appendix 1). Of the 19 vascular species collected by Darwin (Henslow 1838) all but one have been recorded by recent collectors. Most are still common except for *Cordia subcordata, Achryanthes aspera, Neisosperma oppositifolia* and *Laportea aestuans* (Appendix 2).

ISLAND FLORISTICS

INDIGENOUS SPECIES

The relationship between island area and indigenous species richness (Fig. 2) shows a closer fit to a power relationship ($r^2 = 0.87$) than a logarithmic one. When exotic species are included, the power relation is still a good fit ($r^2 = 0.82$), as the larger islands are also the most disturbed and colonized by exotic species.

Cluster analysis for the 22 islands (i.e. including Keeling) based on the species abundance scores shows a clear grouping of islands by size, with Keeling being the most distinct floristically (Table 3, species groups A & E). The strand species form a distinct group (Table 3, species group D) well represented on all but the two smallest islands, Beras and Ampang Kecil, which have areas less than 0.5 ha and support only three of the six common strand species. This strand group comprises *Argusia argentea, Pemphis acidula, Guettarda speciosa, Cocos nucifera, Scaevola taccada* and *Ipomoea macrantha*, all of which have marine dispersal powers.

Some species were found almost exclusively on islands larger than 20 ha, and most of this group were more abundant on Keeling (Table 3, group A). These included the trees *Cordia subcordata, Hernandia nymphaeifolia* and *Pisonia grandis* as well as *Achryanthes aspera, Dicliptera ciliata, Portulaca oleracea, Boerhavia repens, Stenotaphrum micranthum, Lepturus repens* and *Sesuvium portulacustrum.*

Species group B (Table 3) represents those species common on the larger Cocos islands but absent or less abundant on Keeling. Of those species which do occur on Keeling, most are rare there, often recorded from one or two locations only. Species group C consists of three species each found at just a single site on Pulu Panjang. These are *Lepturopetium* sp., *Ximenia americana* and *Enicostema axillare* (Appendix 2).

EXOTIC SPECIES

Only one exotic species, *Turnera ulmifolia*, has spread to all the islands of the Cocos atoll, and it is usually abundant wherever it has established (Table 4). The large but relatively unsettled Pulu Atas has been colonized by six exotic species and five have reached Keeling. Most exotic species are confined to the four large islands that have had or still have intensive settlement. Thirty two of the 63 exotic species occur only on Pulu Panjang and/or Pulu Selma (Table 4, groups C & D, part of A) and nineteen occur on Pulu Panjang only (group C). At the other end of the size scale, the four islands without exotic species (Beras, Blan, Blekok, Jambatan) are all less than 2.5 ha.

VEGETATION PATTERN ON KEELING

Analyses of the transect plot data for Keeling were done with the total set of 26 species recorded in 65 plots along 11 transects. Another 10 species were recorded for North Keeling in reconnaissance. The floristic classification analysis does not exactly correspond with the dominance-based units able to be mapped from aerial photography and ground checking.

Stands of *Pemphis acidula* tall shrubland (2-4 m) and *Cordia subcordata* tall shrubland (3-6 m) occur close to the lagoon shore and are commonly mono-specific (Table 5, site groups 1, 2 & 3), and, where there are finer sediments accumulated, a *Sesuvium portulacustrum* herbland is developed (Table 5, group 1), often lying between or within the two former types (Fig. 3). Site group 4 (Table 5) is characterised by exposed shore halophytes, such as *Portulaca oleracea*, *Lepturus repens* and *Boerhavia repens*, *Cocos* is absent.

Site groups 5 to 8 highlighted floristic sub-units within the closed forest stands characteristically dominated by *Pisonia grandis* and/or *Cocos nucifera* (Table 5, Fig. 3). Group 5 contains the beach halophytes (species group A), group 6 has an understorey of forest mesophytes (species group C), group 7 are stands of pure *Cocos* and *Pisonia*, while group 8 are virtually pure *Pisonia*.

Group 5 mainly represents relatively richer plots (s = 6.7) found within 20 m of the shore which have strand forest dominated by *Cocos* along with halophytic shrubs and herbs which typically occur only near the shoreline. *Pisonia grandis* and *Stenotaphrum micranthum* are constants and the former may be co-dominant on sheltered shores. Some plots in this class fall within areas which are mappable as *Pisonia* shrubland occurring on exposed shores usually behind a beach-fringing *Argusia* shrubland.

Site group 6 (Table 5) corresponds with relatively species-poor areas of forest (mean richness of 3.9) dominated by *Cocos nucifera* and/or *Pisonia grandis*. The associated species include broad-leaved plants such as the climber *Canavalia cathartica*, *Morinda citrifolia*, *Rivina humilis* and *Carica papaya*. Sites in groups 9 & 10 contain species which are uncommon on North Keeling (species groups A & D).

Many species on Keeling have a restricted distribution and most of these are found on the northern peninsula at the entrance to the lagoon or on the north-west lagoon shore and adjacent habitats. The same pattern is evident for the species recorded in transect plots. The richest floristic units, apart from the herblands, are the forest types found near the lagoon entrance and on the northwest side of the island.

VEGETATION CHANGE

A comparison of Fig. 3 with the vegetation map of Keeling Island produced by Gibson-Hill in 1941 (Gibson-Hill 1948) shows geomorphic and vegetational changes evident over the intervening 45 years.

The west-building peninsulas at the lagoon entrances have extended considerably into the lagoon. On the northern peninsula the *Argusia* shrubland mapped by Gibson-Hill is possibly the small area in a similar position mapped in 1986, since it is on a rocky substrate which may have conferred a degree of site stability. The southern arm has a similar clump of *Argusia* that has apparently extended and been flanked by *Cocos* and *Pemphis*. Observations on sand and shingle bars in the lagoon entrance channels show that *Argusia* is the first woody plant to colonize such places in exposed locations and *Pemphis* does the same on more sheltered shores. Both peninsulas show a definite sequence of changing dominance along their strands from *Argusia*, *Pemphis* and *Cocos* on the younger shores to *Cordia* and *Pisonia* on the older ones, reinforcing the interpretation of rapid development of these peninsulas. Being more sheltered, the southern peninsula has developed an area of *Pisonia* forest on its southern end, perhaps largely since 1941.

Another change in the vegetation since 1941 is the loss of the *Argusia* zone along the southwest coastline and possibly on the southeast also. Both locations have 4-5 m high shingle ridges with their seaward faces lying at the repose angle, and show evidence of episodic deposition of shingle into the *Pisonia* zone suggesting storms have removed the *Argusia*.

Gibson-Hill (1948) mapped an area of open grassland on the south-eastern lagoon shoreline which he said was a breeding habitat for shearwaters (*Puffinus* sp.). These birds have not been seen on the island for some years (Stokes *et al.* 1984) and this grassland has now become in parts an open shrubland colonized by *Pemphis*, *Pisonia* and *Argusia* to 3 m high.

VEGETATION OF THE COCOS ATOLL

Cluster analysis of the 106 sample plots on the larger islands (containing 52 species, native and introduced), produced at the ten-group level five major site groups and five further groups represented by a few sites each (Table 6). Floristic definitions of the major site groups emphasise variation in the coconut woodlands and forests in relation to ground layer composition and location relative to the ocean and lagoon. On the most exposed southern and eastern strands of Pulu Atas there are areas of *Argusia* - *Scaevola* shrubland and patches of *Lepturus* - *Triumfetta* herbland on the sand and shingle ridge topping the beach.

The minor site groups reflect distinctive relict communities, mainly on Pulu Panjang and Pulu Luar, where strand trees have survived land clearing or colonized recent deposits. Species such as *Calophyllum inophyllum*, *Guettarda speciosa*, *Hibiscus tiliaceus* and *Barringtonia asiatica* characterize these sites and their distribution over the Cocos atoll is very restricted (Fig. 1, Appendix 2). These species occur scattered along the lagoon shores and on the sheltered west shore of Pulu Panjang, mostly as single trees or small clumps. The largest remaining stands of these species are to be found on Pulu Panjang along the northwest shore and adjacent to the swamp at Bechet Besar; along the

lagoon shore opposite the northern end of the runway; and on the southern lagoon shore of Pulu Luar (Fig. 1).

Pemphis acidula shrubland forms 2-4 m high shrublands scattered all along the lagoon shore, particularly in areas where sand deposition is occurring (e.g. at Tanjong Klikil at the east end of Pulu Panjang) and also at the lagoonward edge of intertidal sandflats. No other species of plants grow in these offshore strands except for an occasional coconut seedling and epiphytic mosses and lichens.

DISCUSSION

FLORA

Island floras originate from a variety of sources depending on their geographic location and suitability of their habitats for immigrant diaspores. The origins of the Cocos (Keeling) biota have long fascinated biologists, particularly those who have examined their plants and insects (see Guppy 1890, Holloway 1982).

Renvoize (1979) suggested that island structure in terms of elevation and geological substrate are key factors in determining the richness of island floras. In this respect, the Cocos (Keeling) islands bear the greatest similarity to the central Indian Ocean islands (Laccadive, Maldive, Chagos) and to only some of the western Indian Ocean group (Cargados Carajos, Tromelin, Agalega, Amirante group, Alphonse, Gloriosa, Europa and Farquhar group). All these low islands have evolved in isolation from a continent, through the combined forces of vulcanism, subsidence and coral growth, and presently rise less than 10 m above sea level.

The low habitat diversity of these islands leads to a flora characterized by very low endemicity with indigenous taxa of pantropical or Indo-Pacific distribution dominating (Renvoize 1979). Cocos (Keeling) is no exception to this general pattern; it has no endemic flora save for the variety *cocosensis* of *Pandanus tectorius*, and with 61 indigenous species (Table 2), is comparable with the Laccadives (40 indigenous species), the Addu atoll in the Maldives (52 species) and the Chagos group (*ca.* 100 species) (Renvoize 1979). It is also similar in species richness to western Pacific atolls such as Nui (44 species) and Kapingamarangi (50 species) (Woodroffe 1986).

The mechanisms of natural dispersal to oceanic islands include wind, ocean currents, birds and bats. Undoubtedly all of these have contributed to the Cocos flora, (even bats have been occasionally sighted, Marlow 1970), but the only agent for which evidence is certain is that of oceanic drift. Most of the strand species are found as seeds on beaches and there is a further component of the flora that is found only on the drift line (Guppy 1890). The main currents around Cocos (Keeling) are westward and would be expected to derive propagules from northern Australia, Torres Strait and Java. These currents are reinforced for most of the year by the prevailing southeast trade winds.

ISLAND RICHNESS AND COMPOSITION

The power relationship established between indigenous species richness and island area (Fig. 2) is similar to that reported for Nui atoll in the Pacific (Woodroffe 1986) and

for the lagoonal islands of Aldabra (Hnatiuk 1979). None of these three species-area relationships support the notion of the small-island effect suggested for Kapingamarangi (Niering 1956, 1963), where very small islands tended to have area-independent species richness.

The six commonest strand species are not always present on the smaller islands and show an increase in frequency of occurrence up to an island size of 10 ha, and are always present above this area (Table 3). If one sets aside these species, i.e. *Argusia argentea*, *Pemphis acidula*, *Guettarda speciosa*, *Cocos nucifera*, *Scaevola taccada* and *Ipomoea macrantha*, then the similarities between the smaller islands are very low. Among the 20 other species, there are only 41 occurrences on the 16 islands smaller than 25 ha. The presence of these species was often correlated with minor and possibly ephemeral habitats; e.g. *Hibiscus tiliaceus* on a small sheltered lagoon-facing shore of Pulu Jambatan where a channel had cut across the prograding western (lagoon) side of the island; *Suriana* on recently formed sandy spits extending lagoonwards on Pulu Siput; and *Mariscus javanicus*, *Fimbristylis cymosa* and *Lepturus repens* where lagoon shorelines distant from inter-island channels had relatively flat shingle embayments at upper tide levels. These observations support the idea that habitat diversity needs to be considered in modelling species richness on islands (Buckley 1982).

Dispersal routes may also contribute to differences between the smaller islands, especially where islands are more likely to receive a high density of propagules. For example, Pulu Labu probably intercepts a higher number of propagules because of its position at the tip of Pulu Atas, where the equatorial current flows northward along Pulu Atas then some sweeps into the lagoon. An exceptionally high abundance of drift seeds was found to occur on the sand dunes at the northern tip of Pulu Atas and in a similar situation on the ocean beach of Pulu Gangsa. This may help to explain the occurrence of *Calophyllum*, *Barringtonia* and *Neisosperma* on the former island and on no other small islands, save for a single *Calophyllum* on Pulu Beras. The latter is also an island which is well situated to receive propagules concentrated by northward transport along the ocean shores of Pulu Selma. However these data are insufficient to suggest such islands have more species for their area, and there are presumably other factors operating, such as stability and age of an island.

Amongst the six larger islands, Pulu Atas has a relatively low richness for its area, possibly related to its more uniform geomorphic structure, rugged ocean coastline and lack of currents flowing along its lagoon shores (although they would have done so in times past before channels closed off).

North Keeling has seven species not found on the main atoll but is also different in composition from the other large islands. Some species (Table 3, group A) are relatively more abundant there, either because of greater areas of suitable habitat on Keeling (e.g. for *Boerhavia repens* and *Portulaca oleracea* in exposed herblands; *Sesuvium portulacustrum* in saltmarshes; *Stenotaphrum micranthum*, *Achryanthes aspera*, *Dicliptera ciliata* in the *Pisonia grandis* rainforest); or due to clearing over the last 160 years (e.g. *Cordia subcordata*, *Hernandia nymphaeifolia* and *Pisonia grandis*). Species group E (Table 3) found only on Keeling may represent in large part the extreme effects of vegetation clearance on the southern atoll. The restricted distribution of *Thespesia populnea* (in a clump of six individuals on Pulu Tikus and in a small mixed stand with *Cordia* on Pulu Luar), probably also represents a relict distribution resulting from extensive cutting in the past, as the bark fibres were once used for netting (Gibson-Hill 1947).

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Table 1. Sampling intensity and the number of native and naturalized (not horticultural) vascular plant species recorded by major collectors and naturalists on the Cocos (Keeling) Islands.

Collector	Year	Period of visit	Islands visited	Number of species
C.R. Darwin	1836	10 days	Cocos atoll	21
H.O. Forbes	1879	22 days	Cocos atoll	38
W.E. Birch	1885	8 days	Cocos atoll	11
H.B. Guppy	1888	10 weeks	Both atolls	53
F. Wood-Jones	1909	15 months	Cocos atoll	46
I.R. Telford	1985	2 weeks	Panjang, Tikus, Atas, Selma, Keeling	93
D.G. Williams	1986/7	9 months	All, including Keeling	130

Table 2. Life forms of the native and naturalized flora.

Origin	Climber	Forb	Graminoid	Seagrass	Shrub	Tree	Total
Native	7	13	11	3	9	18	61
Naturalized	3	29	21	0	10	6	69

Table 3. Two-way classification for **native** species occurring on all islands. Classification based on abundance data standardised by species maximum. The first four letters of the generic name and specific epithet are read vertically. Numerical values represent the abundance scores standardised by species maximum.

Island groups	Species groups
	<----A-----> <----------B----------> <C> <-D--> <-E-->
	|ABPHDSASACPL|CDCCCPTZITEHTCMMMFPSCPVTR|ELX|AIPCSG|V|BN|Q|CEPACL|
	|COOEIECTCOIE|AORAYHHOPEUIRAEAOIRULAIHH|NEI|RPEOCU|I|AE|U|ARALLA|
	|AERRCSHEARSP|EDILPYUYORPBISLRRMERENTEI|IPM|GOMCAE|G|RI|E|NYSLEP|
	|LRTNLURNLDOT|SONOELASMMHIUSAIIBMIRDESZ|CTE|UMPOET|N|RS|E|ATPOOO|
	| | | | | | | |
	|LRONCPAMISGR|BVAISAIMPCATPFBJCCSMITTPA|AMA|AMANTS|M|AO|H|CVVCGA|
	|AELYIOSINURE|OISNTMNAEATIRIIAIYEANEROP|XAM|RACUAP|A|SP|Y|AAAOYE|
	|NPEMLRPCDBAP|NSIOOAVTSTOLOLFVTMRRECIPI|IRE|GCICCE|R|IP|A|TRGBNS|
	|CERPITERICNE|DCAPLRORCATICILARORIRTFUC|LSR|ERDICC|I|AO|L|HIIBAT|
Keeling	|166666666666|1.......11.....14.3.1....|...|456611|.|..|.|666666|
Luar	|.43.111..311|66266416461636555563....66|...|452662|.|..|.|......|
Panjang	|.1361..1.223|11151166666645455634.1...|666|466664|.|1.|.|......|
Selma	|.11....361..|144514444466634223654666..|...|441662|1|..|.|......|
Atas	|.646.......3|...4.1414..665545.41.....|...|646662|.|.1|.|......|
Tikus	|6.3......3..|1162664146...21666..3..1.|...|122661|.|..|6|......|
Cepelok	|.3........11|.........1....5251.......|...|456665|4|..|.|......|
Pandan	|.........1.3|..............444.......|...|666666|.|..|.|......|
Ampang	|...........|.............6...3......|...|456665|6|..|.|......|
Kembang	|...........|........1...154...6......|...|415665|.|..|.|......|
Wak-Idas	|...........|.............4...3.......|...|356665|.|..|.|......|
Blekok	|...........|..............2.........|...|346562|.|..|.|......|
Blan	|...........1|.........................|...|156615|.|..|.|......|
Kambing	|...........1|.........................|...|3456.4|.|..|.|......|
Kelapa Satu	|...........|.................1......|...|.5.665|.|..|.|......|
Blan Madar	|...........|................1........|...|36.664|.|..|.|......|
Maraya	|.........11.|..............3........|...|352664|.|..|.|......|
Siput	|...........|............1.....6.....|...|3.2666|.|..|.|......|
Jambatan	|...........|..........1.............|...|4.2665|.|..|.|......|
Labu	|...........|...4...........4........|...|464665|.|66|.|......|
Beras	|...........|...1.....................|...|4..46.|.|..|.|......|
Ampang Kecil	|...........|.........................|...|61..6.|.|..|.|......|

Table 4. Two-way classification for **exotic** species occurring on all islands. Classification based on abundance data standardised by species maximum. The first four letters of the generic name and specific epithet are read vertically. Numerical values represent the abundance scores standardised by species maximum.

Island groups	Species groups
	<----------A---------> <-B-> <--------C--------> <--D--->
	|BTVEEEMACDEEESDSHCSMRP|LCSPR|BBCCCHDCCEIPDAEBSGS|CS|RTT|IS|VS|CBLSSIAZ|
	|OREURUUUEALULPIPEYTAHH|EYCHI|OREHYIEHOMMAEPRRORT|AI|IRU|SE|EO|AREOENEE|
	|EIRPAPNSNCEPEOGEDNACOY|PNOYV|TENLPPSRNIPSSLIARAR|RD|CIR|CS|RL|SYUNNDRP|
	|RDNHGHTTCTUHURIRYOCRES|IOPLI|HYCOEPMYYLESMUOCGSI|IA|IPN|HB|NA|UOCCNIVH|
	| | | | | | | | | |
	|DPCHTPCIEAICRISACDJASM|VADNH|BDCBPLTABSCFBMMBBSA|PA|CTU|MG|CA|EPLOOHLR|
	|IRIIERANCENYUNESOAATPI|IRUOU|LIIAOORCOOYOIUERIPS|AC|ORL|UR|IM|QIELCIAO|
	|FONRNOLUHGDADDTSRCMRAN|RCLDM|ASLRLNIINNLEPTYIC1I|PU|MIM|TA|NE|UNUECRNS|
	|FCETESALIYITEIIUYTAOTI|GUCII|DTIBYGFCACITIIEZO0A|AT|MFI|IN|ER|INCRISAE|
Keeling	|.....4|....6|.....|66|.1.|..|..|.....|
Atas	|....4.....|61..6|.....|..|.65|..|..|.....|
Luar	|6614.....664.4|...61|.....|..|6.5|66|..|.....|
Tikus	|...11661.....111.6..6|.....|.....|..|1.6|..|66|.....1|
Selma	|116466611666666661664|.....|.....|..|164|..|..|66666666|
Panjang	|666666666666166611111|66111|6666666666666666666|..|..6|..|..|.....|
Kambing	|.....|..6..|.....|..|..2|..|..|.....|
Ampang Kecil	|.....|.....|.....|..|..1|..|..|.....|
Ampang	|.....|.....|.....|..|..5|..|..|.....|
Cepelok	|.....|.....|.....|..|..5|..|..|.....|
Pandan	|.....|.....|.....|..|..5|..|..|.....|
Siput	|.....|.....|.....|..|..5|..|..|.....|
Labu	|.....|.....|.....|..|..5|..|..|.....|
Blan Madar	|.....|.....|.....|..|..5|..|..|.....|
Maraya	|.....|.....|.....|..|..5|..|..|.....|
Wak-Idas	|.....|.....|.....|..|..4|..|..|.....|
Kembang	|.....|.....|.....|..|..4|..|..|.....|
Kelapa Satu	|.....|.....|.....|..|..4|..|..|.....|

Table 5. Two-way classification for all species recorded in transect plots on North Keeling Island. First letter of the site code represents the island name, second and third letters refer to the aspect of the ocean coastline.

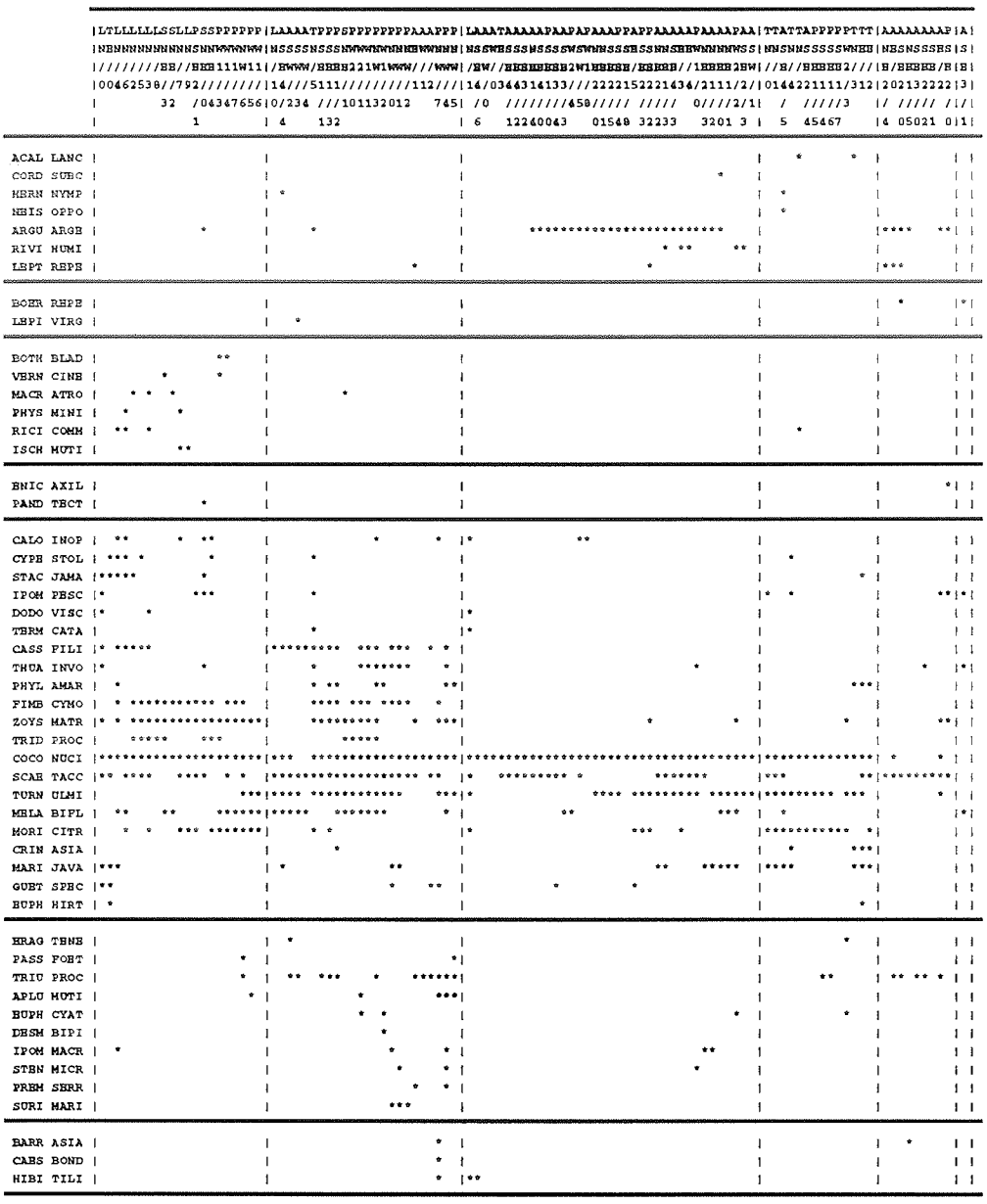
Site groups / Species groups

		<-A->	<---B--->				<----C---->	<-D->
		ASA	AGLGBLP	H	F	PS	CRCFCCDMT	ISP
		CIC	RTAUOEO	A	A	BE	AIOIOAIOR	PCR
		ADH	GEPHEPR	R	S	MS	NVCSRRCRI	OAE
		LAR	UNOTRTT	I	P	PU	AIOODILIP	MBM
		LAA	AMRSRRO	J	V	AP	CHNGSPCCT	MTS
		ACS	RIUPBBL	A	A	CO	AUURUAIIR	AAE
		NUP	GCDBPPE	V	G	IR	TMCABPLTI	CCR
		CTE	BRECBER	A	I	DT	HIINCAIRP	RCR
1	KN/0		*			**	*	
	KSE/0					**		
	KN/1					*		
2	KE1/4					*		
	KS/7					*		
	KSW/2					*		
3	KN/2						*	
	KSW/1						*	
4	KN/3		* **				* *	
	KW2/6		* **	*			**	
	KSE/1		***			**	*	
	KSE/2		** ***			*	*	
	KS/0		** ***				*	
	KSE/3		***		*	*		
	KS/6		* ***			*		
	KE1/0		** **				*	
5	KE1/1		* ***				**	
	KW1/5		** * *				**	
	KS/1		** *				**	
	KW1/0		** *				**	
	KW3/0		*** * *				****	
	KE2/5		** **			*	***	*
	KNA1/2	*	**** *				***	
	KNA2/0		**** *				**	
	KNA2/1		***				***	
	KE2/4		*				***	* *
	KW3/7		*				* ***	**
	KNA2/3		*				***	*
6	KN/4						*** *	
	KN/8		*				** *	
	KW2/3						* ** *	
	KN/7						** **	
	KW3/3						** *	
	KW3/4						*** ***	
	KE1/3						***	
	KE2/3						***	
	KW1/1						***	
	KW2/5	*					***	
	KW3/1						****	
	KW2/1						***	
	KW2/2						*** *	
	KW3/2						**** *	
	KW3/6						* *** *	
	KW2/4						* ** *	
	KN/5		*				** *	
	KS/5		*				**	
	KE1/2		*				**	
	KE2/2		*				**	
	KNA1/1		*				**	
	KNA1/0		* *			*	**	
	KW2/0		**				***	
7	KN/9						**	
	KN/10						**	
	KNA2/2						**	
	KS/2						**	
	KS/3						**	
	KS/4						**	
8	KN/6		* *				*	
	KW1/4		*				*	
	KW1/2						*	
	KW1/3						*	
9	KE2/0							**
	KE2/1		*				*	*
	KSW/0						*	*
10	KW3/5	***					* *	

Table 6. Two-way classification for all species recorded in transect plots on the Cocos atoll. First letter of the site code represents the island name, second and third letters refer to the aspect of the ocean coastline. Asterisks indicate presence of a species.

Species groups

Site groups



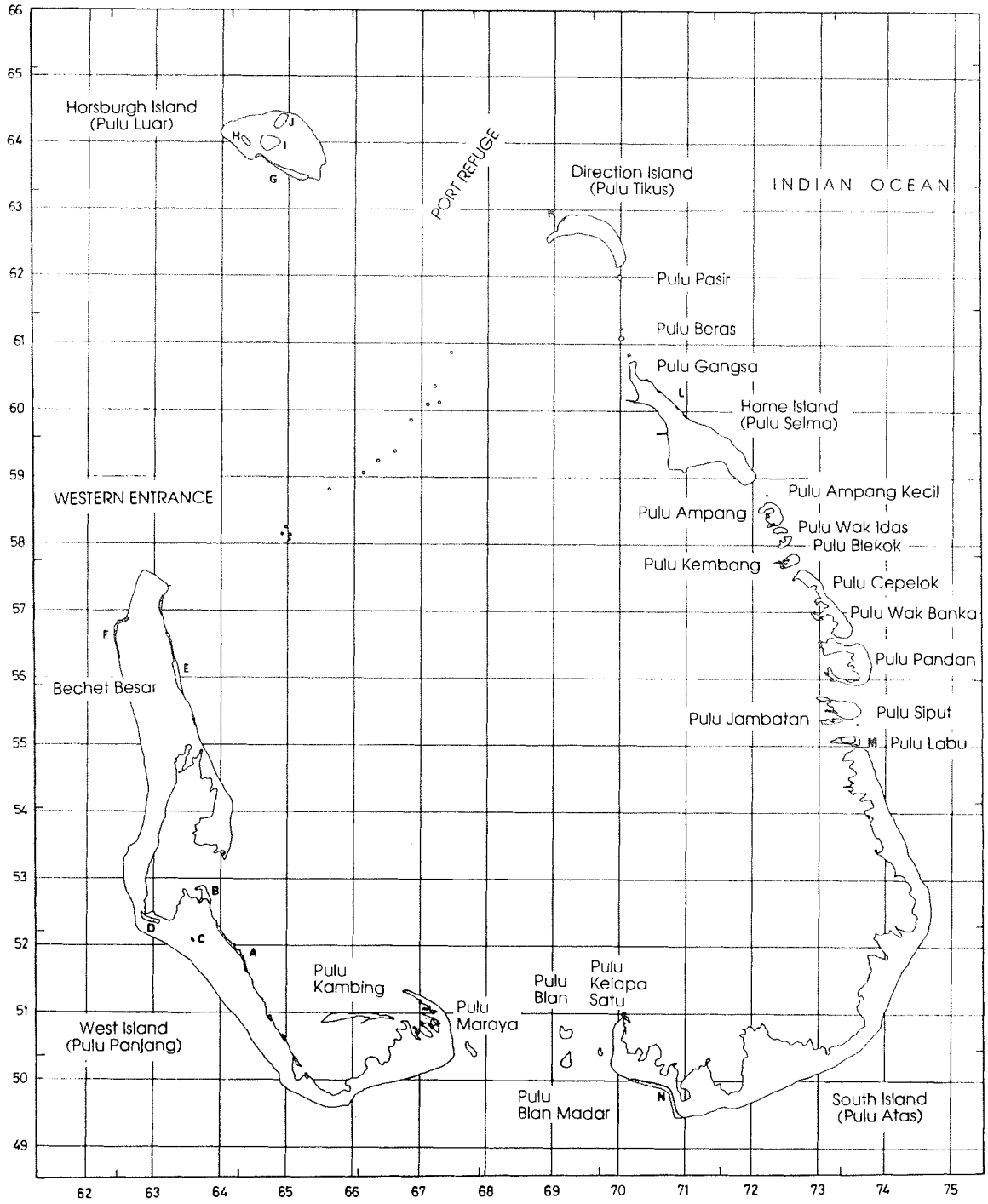


Figure 1. Location map showing island names, localities mentioned in the text and remnant vegetation patches on the Cocos atoll. Refer to Appendix 3 for a description of the remnant vegetation units. Gridlines represent 1000 m grid of the Australian Map Grid, Universal Transverse Mercator Projection. Map base derived from R.A.S.C. Series R811 Sheet Special Cocos Island 1979.

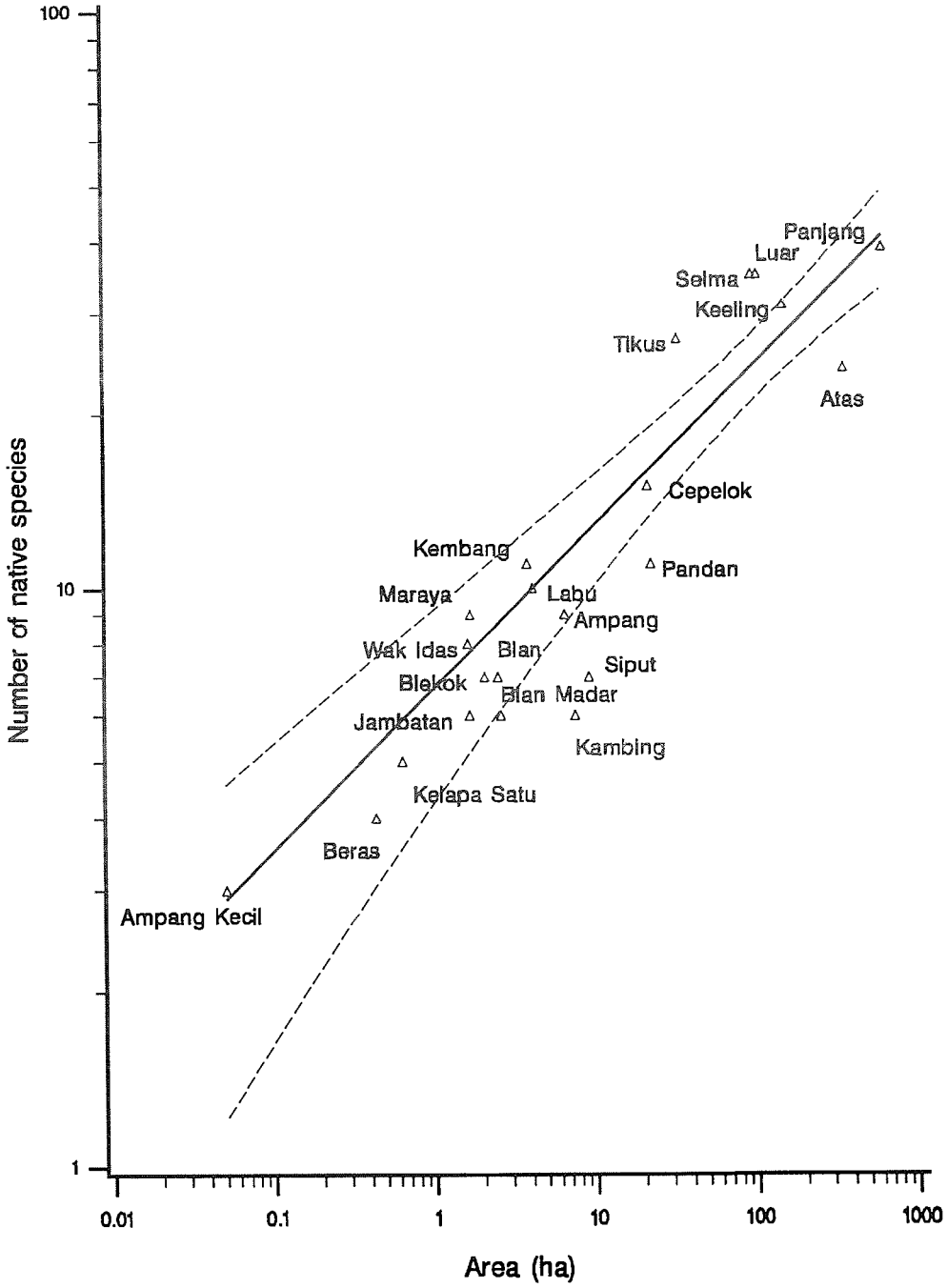


Figure 2. Species-area relationship for indigenous plant species richness for the 21 vegetated islands of the Cocos atoll and the island of North Keeling, showing approximate 95% confidence limits. Non-linear regression fitted to obtain the equation $s = 6.73a^{0.28}$.

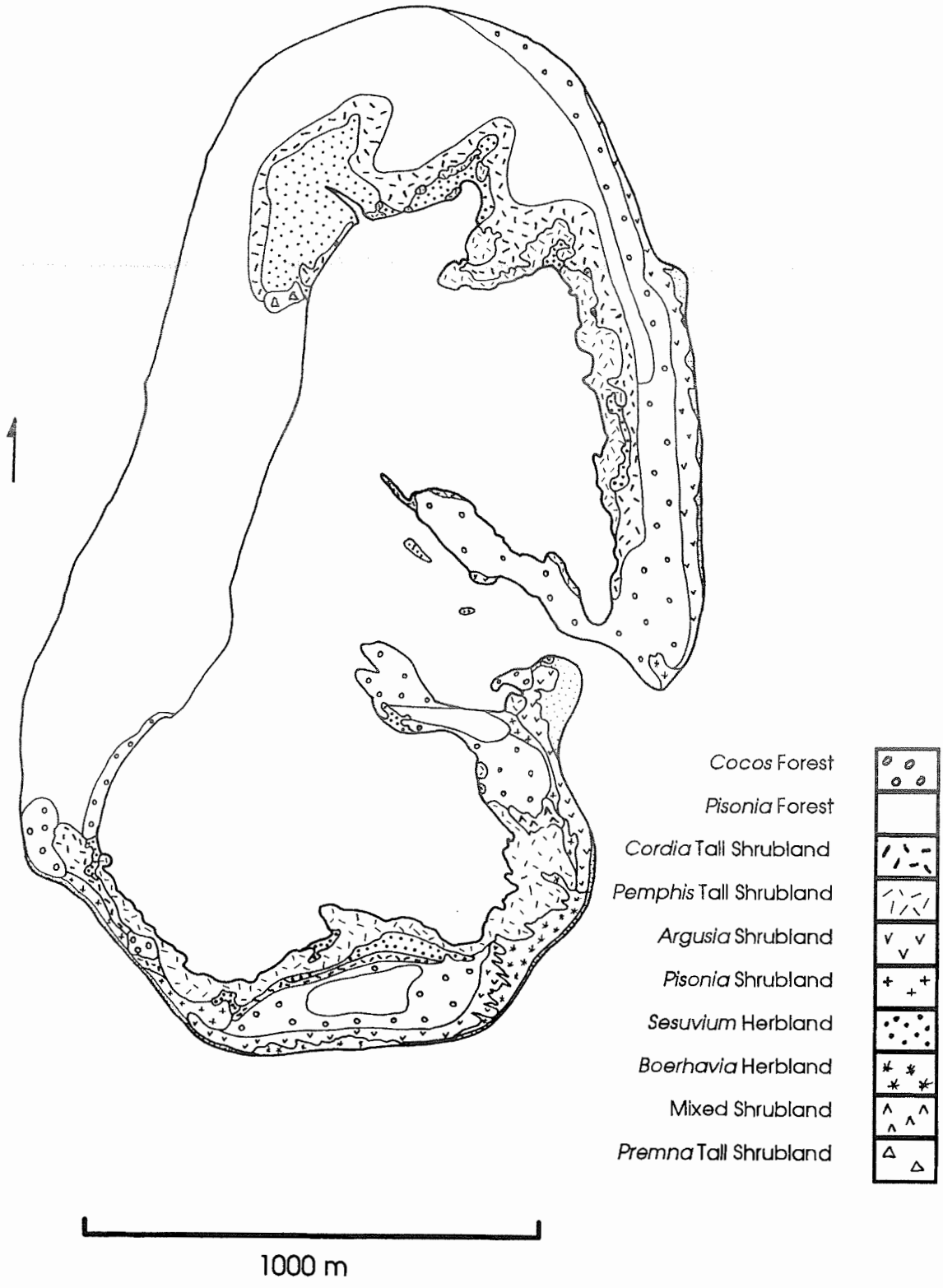


Figure 3. Vegetation map of North Keeling Island.

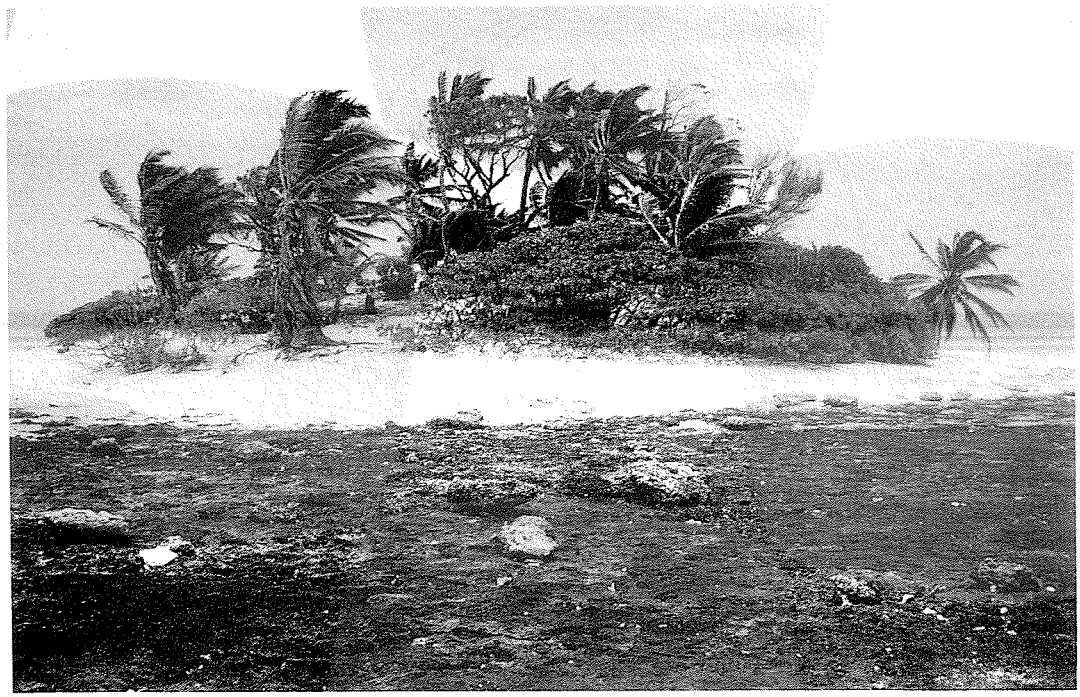


Figure 4. Pulu Beras, one of the smallest vegetated islands, with a cover of *Cocos nucifera*, *Argusia argentea* and *Scaevola taccada*.

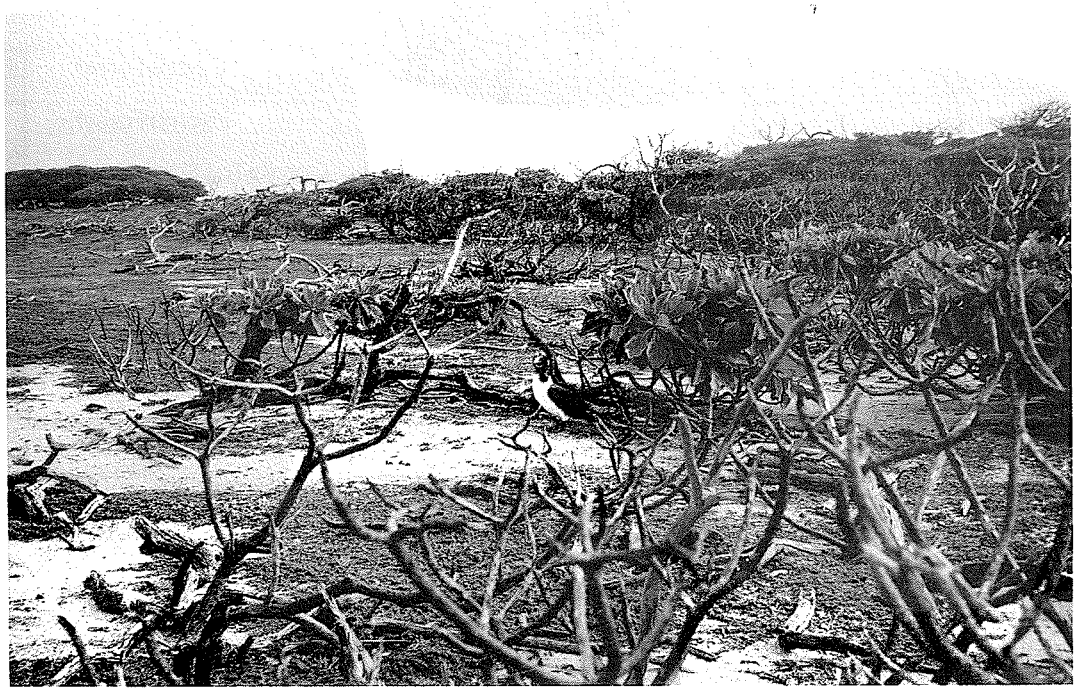


Figure 5. *Boerhavia repens* herbland grading into wind-sheared *Argusia argentea* shrubland on the south-east coast of North Keeling island. This is the breeding habitat for the Brown Booby.

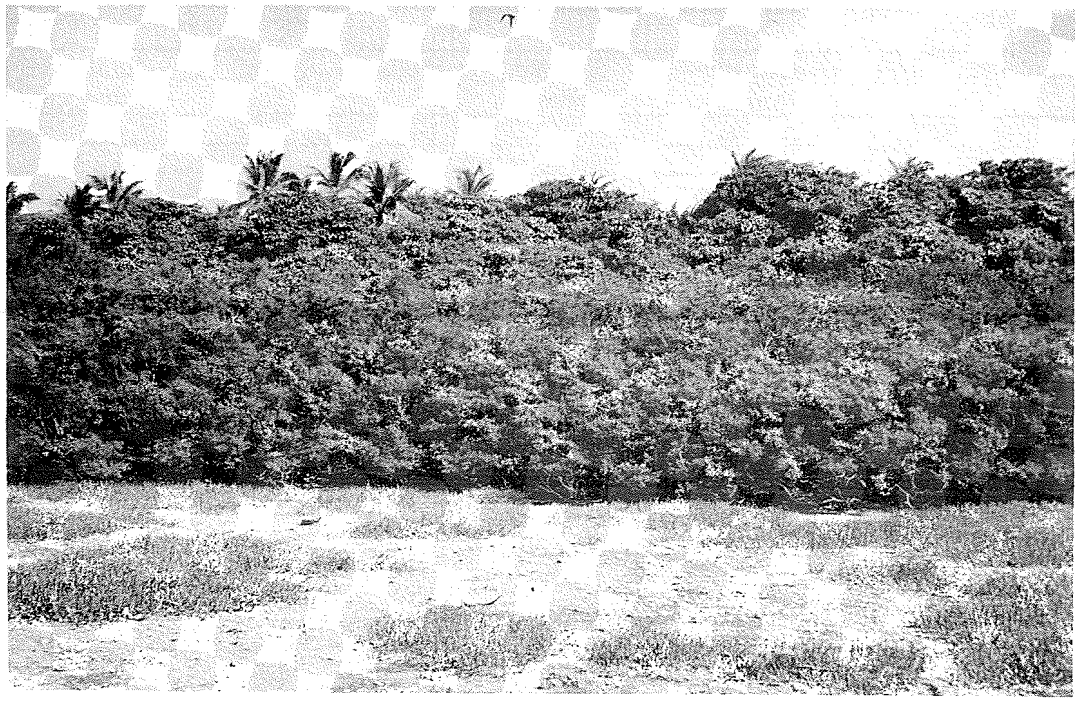


Figure 6. *Sesuvium* herbland adjoining *Pemphis* shrubland with *Cocos -Pisonia* forest in the background, on North Keeling island.

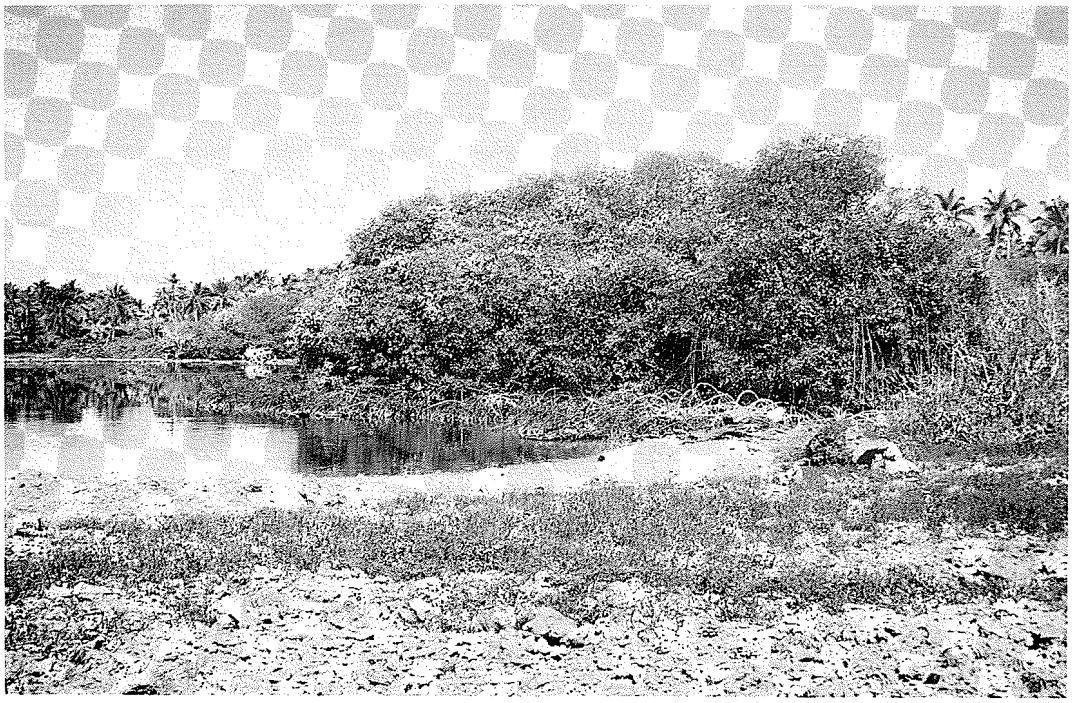


Figure 7. *Rhizophora apiculata* grove on Pulu Luar lagoon. *Sesuvium* herbland on coral shingle in the foreground.

Appendix 1. Vascular plant species list for the Cocos (Keeling) Islands. Asterisk indicates introduced species.

Family		Generic Name	Specific Epithet	Authority	Var./ Subsp.	Common Name	Local Name
ACANTHACEAE		Dicliptera	ciliata	Decne.			
AIZOACEAE		Sesuvium	portulacustrum	(L.) L.		Sea Purslane	
AMARANTHACEAE		Achryanthes	aspera	L.	var villosior (Henslow) D.Porter	Chaff Flower	
	*	Aerva	lanata	(L.) Schult.			
APOCYNACEAE		Neisosperma	oppositifolia	(Lam.) Fosb. & Sachet			Kayu Laki
ASTERACEAE	*	Austroeupatorium	inulifolium	(Humb.,Bonpl. et Kunth)King et H.Robinson		Stinkweed	
	*	Conyza	bonariensis	(L.) Cronquist		Fleabane	
	*	Eleutheranthera	ruderalis	(Sw.) Sch. Bip.			
	*	Emilia	sonchifolia	(L.) DC.			
		Melanthera	biflora	(L.) Wild.		Beach Sunflower	
	*	Sonchus	oleraceus	L.		Milk Thistle	
	*	Synedrella	nodiflora	(L.) Gaertn.			
	*	Tridax	procumbens	L.			
	*	Vernonia	cinerea	(L.) Less.	var. cinerea		
	*	Vernonia	cinerea	(L.) Less.	var lanata J.T. Koster		
BORAGINACEAE		Argusia	argentea	(L.f.) Heine		Octopus Bush	Kayu Sireh
		Cordia	subcordata	Lam.		Sea Trumpet	Geron-ggang
BRASSICACEAE	*	Lepidium	virginicum	L.			
CAESALPINIACEAE		Caesalpinia	bonduc	(L.) Roxb.		Nicker Nut	Kelenchi
	*	Senna	occidentalis	(L.) Link			
CAMPANULACEAE	*	Hippobroma	longiflora	(L.) G.Don			
CAPPARACEAE		Cleome	gynandra	L.			
CARICACEAE	*	Carica	papaya	L.		Pawpaw	Katis
CASUARINACEAE		Casuarina	equisetifolia	L.	subsp. equisitifolia	Coastal Sheoak	Cemara
CLUSIACEAE		Calophyllum	inophyllum	L.		Alexandrian Laurel	Nyampl-ong
COMBRETACEAE		Terminalia	catappa	L.		Sea Almond	Ketapang
CONVOLVULACEAE		Ipomoea	macrantha	Roem. & Schult.		Moon Flower	
CONVOLVULACEAE		Ipomoea	pes-caprae	(L.) R.Br.	subsp. brasiliensis (L.) Ooststr.	Goat's-foot Convolvulus	Kangkong Meryap
CRASSULACEAE	*	Bryophyllum	pinnatum	(Lam.) Oken			
EUPHORBIACEAE		Acalypha	indica	L.			
		Acalypha	lanceolata	Willd.			
	*	Breynia	disticha	J.R.Forst. & G.Forst.			
		Euphorbia	atoto	G. Forst.			
	*	Euphorbia	cyathophora	Murray		Dwarf Poinsettia	
	*	Euphorbia	hirta	L.			

EUPHORBIACEAE	*	*Euphorbia*	prostrata	Aiton			
		Phyllanthus	amarus	Schumach & Thonn.			
	*	Ricinus	communis	L.		Castor Oil Plant	Pokok Jaru Jarak
	*	Sauropus	androgynus	(L.) Merr.			Keretu
FABACEAE	*	Alysicarpus	vaginalis	(L.) DC.			
		Canavalia	cathartica	Thouars. in A.N. Desvaux		Sea Bean	
	*	Crotalaria	retusa	L.	var. retusa		
	*	Desmodium	triflorum	(L.) DC.			
		Erythrina	variegata	L.		Coral Tree	Kayu Dedap
	*	Indigofera	hirsuta	L.			
	*	Macroptilium	atropurpureum	(DC.) Urb.		Siratro	
	*	Sesbania	cannabina	(Retz.) Poir.	var. cannabina		
	*	Sesbania	grandiflora	(L.) Poir.			Turi
		Vigna	marina	(Burm.) Merr.			
FLACOURTIACEAE	*	Muntingia	calabura	L.			Buah Cheri
GENTIANACEAE		Enicostema	axillare	(Lam.) A. Raynal	subsp. littorale (Blume) A.Raynal		
GOODENIACEAE		Scaevola	taccada	(Gaertn.)Roxb.		Sea Lettuce	Kayu Kankong
HERNANDIACEAE		*Hernandia*	nymphaeifolia	(C.Presl) Kubitzki		Sea Hearse	Kayu Jambu Hutan
LAURACEAE		Cassytha	filiformis	L.		Devil's Twine	
LECYTHIDACEAE		Barringtonia	asiatica	(L.) Kurz.		Box Fruit	Kayu Besagi
LYTHRACEAE		Pemphis	acidula	J.R.Forst. & G.Forst.			Kayu Keriting
MALVACEAE		Hibiscus	tiliaceus	L.	subsp. tiliaceus	Cotton Tree	Pokok Waru
	*	Sida	acuta	Burm. f.			
		Thespesia	populnea	(L.) Sol. ex Correa		Portia Tree	Waru Hutan
MIMOSACEAE	*	Leucaena	leucocephala	(Lam.) de Wit		Leucaena	Peteh
MYRTACEAE	*	*Eugenia*	sp.				Jambu Ayer
	*	Psidium	guajava	L.		Guava	Jambu Biji
NYCTAGINACEAE	*	Boerhavia	albiflora	Fosberg			
	*	Boerhavia	diffusa	L.			
		Boerhavia	repens	L.			
		Pisonia	grandis	R.Br.		Pisonia	Ampol
OLACACEAE		Ximenia	americana	L.		Yellow Plum	Rukam
PASSIFLORACEAE	*	Passiflora	foetida	L.	var hispida (DC. ex Triana & Planch.) Killip	Stinking Passionflower	
PHYTOLACCACEAE	*	Rivina	humilis	L.		Coral Berry	
PORTULACACEAE		Portulaca	oleracea	L.		Pigweed	
RHIZOPHORACEAE		Rhizophora	apiculata	Blume		Spider Mangrove	

RUBIACEAE		Guettarda	speciosa	L.			Kembang Melati Hutan
		Morinda	citrifolia	L.		Cheesefruit	Mengkudu
	*	Oldenlandia	corymbosa	L.			
	*	Spermacoce	assurgens	Ruiz & Pav.			
RUTACEAE	*	Triphasia	trifolia	(Burm.f.) P.Wilson			Buah Kengkit
SAPINDACEAE		Allophylus	cobbe	(L.) Blume			
		Dodonaea	viscosa	Jacq.	subsp. viscosa	Hopbush	
SCROPHULARIACEAE	*	Scoparia	dulcis	L.			
	*	Striga	angustifolia	(D.Don) Saldanha			
SOLANACEAE	*	Physalis	minima	L.			Chepelok
	*	Solanum	americanum	Mill.		Blackberry Nightshade	
SURIANACEAE		Suriana	maritima	L.			
TILIACEAE		Triumfetta	repens	(Blume) Merr. & Rolfe		Bingit Burr	
TURNERACEAE	*	Turnera	ulmifolia	L.			
URTICACEAE		Laportea	aestuans	(L.) Chew.			
VERBENACEAE	*	Clerodendrum	indicum	(L.) Kuntze			
		Clerodendrum	inerme	(L.) Gaertn.		Sorcerer's Flower	
	*	Phyla	nodiflora	(L.) Greene			
		Premna	serratifolia	L.			
	*	Stachytarpheta	jamaicensis	(L.) J.Vahl		Blue Snakeweed	
		Vitex	trifolia	L.			
ARECACEAE		Cocos	nucifera	L.		Coconut	Kelapa
COMMELINACEAE	*	Rhoeo	spathacea	(Sw.) Stearn			
CYMODOCEACEAE		Syringodium	isoetifolium	(Asch.) Dandy		sea grass	
		Thalassodendron	ciliatum	(Forssk.) Hartog		sea grass	
CYPERACEAE		Cyperus	stolonifer	L.		Nut Grass	
		Fimbristylis	cymosa	R.Br.			
		Mariscus	javanicus	(Houtt.) Merr.& F.P.Metcalfe			
	*	Pycreus	polystachyos	(Rottb.) P.Beauv.			
		Queenslandiella	hyalina	(Vahl) F.Ballard			
HYDROCHARITACEAE		Thalassia	hemprichii	(Ehrenb.) Asch.		sea grass	
LILIACEAE		Crinum	asiaticum	L.		Crinum Lily	
	*	Zephyranthes	rosea	(Spreng.) Lindl.			
PANDANACEAE		Pandanus	tectorius	Park.	var. cocosensis B.C.Stone	Screw Palm	Pandan
POACEAE	*	Apluda	mutica	L.			
	*	Bothriochloa	bladhii	(Retz.) S.T.Blake			
	*	Brachiaria	brizantha	(Hochst.ex A.Rich.)Stapf			
	*	Cenchrus	ciliaris	L.			
	*	Cenchrus	echinatus	L.		Sand Burr	
	*	Chloris	barbata	Sw.			

POACEAE	**	Chrysopogon	acicularis	(Retz.) Trin.		
	*	Cynodon	arcuatus	J.Presl. & C.Presl.		
	*	Cynodon	dactylon	(L.) Pers.		Couch
	*	Dactyloctenium	aegyptium	(L.) Willd.		
	*	Desmostachya	bipinnata	(L.) Stapf		
	*	Digitaria	setigera	Roth		
	*	Eleusine	indica	(L.) Gaertn.		Crowsfoot Grass
	*	Eragrostis	tenella	(L.) P.Beauv. ex Roem. & Schult.		
	*	Eriochloa	meyeriana	(Nees) Pilg.		
	*	Imperata	cylindrica	(L.) P.Beauv.	var. major	Bladey Grass
	*	Ischaemum	muticum	L.		
		Lepturopetium	sp. aff. marshallense			
		Lepturus	repens	(G.Forst.) R.Br.		Stalky Grass
	*	Panicum	repens	L.		
		Paspalum	vaginatum	Sw.		
	*	Sporobolus	fertilis	(Steud.) Clayton		Sand Couch
		Stenotaphrum	micranthum	(Desv.) C.E.Hubb.		Beach Buffalo Grass
		Thuarea	involuta	(G.Forst.) R.Br.ex Roem. & Schult.		Bird's-beak Grass
		Zoysia	matrella	(L.) Merr.	subsp. matrella	
	*	Unidentified	sp.			

Appendix 2. Notes on plant species of restricted distribution on the Cocos (Keeling) Islands, along with collection numbers held at CBG.

Achryanthes aspera: Common on Keeling and found elsewhere only near some senescent *Pisonia* trees around the small lagoon on Pulu Luar. [D.G. Williams 45,52,211]

Barringtonia asiatica: A solitary tree of great stature occurs on Pulu Panjang with numerous supressed-advance seedlings underneath the canopy. The only other *Barringtonia* seen were a few saplings in the recent strand forest along the lagoon shore 150 m south of the northeast point of Pulu Panjang. [D.G. Williams 110]

Casuarina equisetifolia: Planted indiviuals are found in and near the settlements on Pulu Panjang and Pulu Selma and one large tree is on the lagoon shore north of the kampong. Guppy (1890) reported that the plant was introduced and spreading from island to island but no evidence was found for the latter. No seedlings were seen. [D.G. Williams 155]

Cordia subcordata: Now occurs on the Cocos atoll only as large senescent individuals along the lagoon shore. No young plants were seen, although germination was common on North Keeling lagoon shore in April. [D.G. Williams 20,54]

Enicostema axillare: Known only from two adjacent locations on southern Pulu Panjang, where it occurs amongst *Zoysia matrella* and *Ipomoea pes-caprae* in open coconut woodlands. It occurs from the ocean beach up to 100 m inland. Although flowering freely, these populations appear to be extending largely by rhizome extension, to judge by their compact, circular distribution. [D.G. Williams 79]

Erythrina variegata: A small but healthy grove of trees found at the north end of Keeling in *Pisonia* forest [D.G. Williams 53]. Likewise *Allophylus cobbe* [D.G. Williams 44,48] and *Cleome gynandra* [D.G. Williams 36] were found only in this area, the latter at the upper limit of the saltmarsh.

Laportea aestuans: Previously collected here only by Darwin on the Cocos atoll in 1836. Since collected only on the beach top along the western shore of North Keeling island. [D.G. Williams 154]

Lepturopetium sp.: A western Pacific genus of putative hybrid origin (Fosberg and Sachet 1982), found here only at the southern end of the runway on Pulu Panjang, growing on low-lying land occasionally inundated by rain or heavy seas. [D.G. Williams 267]

Neisosperma oppositifolia: Found occuring as a stand only on Pulu Labu, where there are twenty or so mature trees forming abundant fruits. A solitary specimen without fruit was found on Pulu Atas and two apparently planted trees occur in the Pulu Panjang settlement. [D.G. Williams 25,145,175]

Pandanus tectorius var. *cocosensis*: The only stands are on Pulu Selma where some of the clumps on high dunes have died out recently, possibly due to firing. A single clump on Pulu Panjang at the entrance to Telok Jambu appears to be all male, and therefore probably a single genet representing a solitary establishment event. [D.G. Williams 103]

Pisonia grandis: A few small clumps remain on the Cocos atoll of what must have been the dominant tree on the larger, higher islands before settlement. [D.G. Williams 21,43]

Rhizophora apiculata: Occurs around the saline swamp on Pulu Luar and produces numerous seedlings there. One established seedling was found on the southern point of Pulu Selma but had disappeared a year later. Guppy (1890) stated that the populations were derived from beach drift planted on Pulu Luar by J. G. Clunies-Ross about 1850-60. [D.G. Williams 171]

Suriana maritima: Occurs, in any abundance, only on recent sand deposits. Said by Guppy (1890) to have first colonized the atoll in about 1850, when it appeared on the ocean side of Pulu Cepelok, although it was not found there in this survey. [D.G. Williams 176]

Ximenia americana: Found only as a few plants on the lagoon shore of Pulu Panjang. [D.G. Williams 183]

Appendix 3. Remnant native vegetation of the Cocos atoll referred to map units indicated by letters on Fig. 1. The map does not show the following types of native vegetation:-

- *Pemphis acidula* and *Suriana maritima* shrublands on sheltered shores;
- *Scaevola taccada* and *Argusia argentea* shrublands along exposed coastlines;
- solitary individuals or small clumps of native species.

Pulu Panjang (West Island)

A Major area of strand forest with single large *Barringtonia asiatica*, several *Cordia subcordata*, *Calophyllum inophyllum*, *Hibiscus tiliaceus*, *Hernandia nymphaeifolia*, and *Morinda citrifolia*.

B Strand vegetation of *Pemphis acidula* with the only stand of *Pandanus tectorius* on West Island (burnt in October 1987) and some *Hibiscus tiliaceus* and *Hernandia nymphaeifolia*.

C A small clump of mature *Pisonia grandis*.

D Scattered individuals of *Hernandia nymphaeifolia* occur in this area, most of which is cleared for the aerial field.

E Strand lined with patches of large *Calophyllum inophyllum* and freshwater swamp lined with *Hibiscus tiliaceus*. *Suriana maritima*, *Guettarda speciosa* and *Pemphis acidula* occur locally.

F *Guettarda speciosa* and *Scaevola taccada* scrub along the strand opposite the aerial field and merging northward with tall *Guettarda speciosa* and *Calophyllum inophyllum* strand forest which extends inland, indicating a former shoreline.

Pulu Luar (Horsburgh Island)

G Well developed strand forest of *Calophyllum inophyllum*, *Terminalia catappa*, *Dodonaea viscosa*, *Hibiscus tiliaceus*, *Premna serratifolia*, *Guettarda speciosa*.

H Stand of *Thespesia populnea* and *Cordia subcordata* trees growing along a saltwater seep.

I Disturbed forest of *Morinda citrifolia*, *Premna serratifolia*, *Guettarda speciosa*, *Terminalia catappa*. Associated with a seasonally water-logged swamp dominated by *Mariscus javanicus*.

J Saltwater swamp with fringing *Cordia subcordata*, *Rhizophora apiculata* and a few *Pisonia grandis*. *Achryanthes aspera* and *Sesuvium portulacustrum* also occur.

Pulu Tikus (Direction Island)

K A small clump of *Thespesia populnea* occurs here amongst *Scaevola taccada* at the top of a rubble beach.

Pulu Selma (Home Island)

L Scattered clumps of *Pandanus tectorius* occur on the coastal dune; some burnt in 1987. *Guettarda speciosa* and *Premna serratifolia* are also present.

Pulu Labu

M The interior of this island has several large *Barringtonia asiatica* and a number of small and large *Neisosperma oppositifolia.*

Pulu Atas (South Island)

N Strand forest ranging from exposed to sheltered with *Calophyllum inophyllum* mainly, but also *Hibiscus tiliaceus*, *Guettarda speciosa*, and *Premna serratifolia.*