Mapping and evaluating Capricornia Cays vegetation and regional ecosystems

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Front Cover: Design by Will Smith

Cover plates: Top row: Coral reef edge on North West Island; sunset over the reef flat; and *Pisonia grandis* low closed-forest and herbland boundary on Lady Musgrave Island.

Bottom row: White-capped noddys *Anous minitus* sunbaking: large *Pisonia grandis* tree: green turtle *Chelonia mydas* returning to sea on Lady Musgrave Island. All photos by VJ Neldner.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Executive summary

Flora

1. One hundred and thirty-one species were recorded as occurring naturally on the Capricornia Cays during the 2007/08 surveys of terrestrial flora. This includes 44 native coral cay species and 87 naturalised non indigenous species. The naturalised flora comprises 77 exotic and 10 naturalised mainland species.
2. Two new records of native plant species were recorded:
   - *Hernandia nymphaeifolia* (Jack-in-a-box tree), a seashore tropical tree recorded at North West Island, is a new record for the Port Curtis pastoral district and marks the southern limit of its occurrence in Australia.
   - An undescribed *Boerhavia* species (*Boerhavia* sp. Bargara L.Pedley 5382) was recorded at Lady Elliot Island. It is a new record for Capricornia Cays.
3. The 14 new naturalisations for the study area include: Bermuda grass (*Cynodon nlemfuensis* var. *nlemfuensis*) and creeping Cinderella weed (*Calyptocarpus vialis*) at Heron Island; creeping amaranth (*Amaranthus blitum*) at One Tree Island; sorghum (*Sorghum bicolor*) at North West Island; sisal hemp (*Agave sisalana*), Gomphrena weed (*Gomphrena celosioides*), wandering Jew (*Tradescantia pallida*), oysterplant (*T. spathacea*), green fathen (*Chenopodium murale*), four o'clock plant (*Mirabilis jalapa*), snake weed (*Stachytarpheta cayennensis*) and moonlight cactus (*Hylocereus undatus*) at Lady Elliot Island. Two mainland native species were observed to be naturalising at Lady Elliot Island: dentella (*Dentella repens*) and pennywort (*Hydrocotyle acutiloba*).
4. Several native coral cay species have a reduced distribution since earlier regional flora reports. *Spinifex sericeus* was not recorded on eight islands where it had been recorded previously: North Reef, Tryon, Heron and One Tree Islands, the Hoskyn Islands, Lady Musgrave and Lady Elliot Islands.
5. Significant infestations of already established naturalised species were recorded during the 2007/08 surveys for several species: American sea rocket (**Cakile edentula* – 13 islands), Mossman River grass (**Cenchrus echinatus* – 9 islands), crowsfoot grass (**Eleusine indica* – 7 islands), corky passionfruit (**Passiflora suberosa* – North West and Lady Elliot islands), common milk thistle (**Sonchus oleracea* – 10 islands), cobbler's pegs (**Bidens pilosa* – 9 islands) and Jersey cudweed (+*Pseudognaphalium luteoalbum* – 8 islands). (* denotes exotic species to Australia, while + denotes a native mainland species that is not indigenous to the coral cays).
6. Weed control on Lady Elliot Island needs special consideration as it is a major undertaking. Forty-seven species (36.1%) of weeds found on Lady Elliot Island were not present on any other Capricornia Cays. Without Lady Elliot Island, exotic species for the region would be reduced to 39 species, i.e. 30% of the total flora.
7. Analyses of plant species richness and floral composition indicated that the southern and northern coral cays of the Great Barrier Reef are significantly different.

Vegetation communities

1. Capricornia Cays *Pisonia grandis* closed-forests reached heights of more than 20m and are some of the most well developed forest of its kind in Australia.
2. *Ximenia americana* closed-scrub at Tryon Island represents the only known occurrence of this vegetation type on coral cays in Queensland.

3. The vegetation condition of most native communities was good indicating healthy growth and active regeneration. However, recent history has shown that *P. grandis* is highly vulnerable to scale insect damage.
4. Seashore herbland species compositions are changeable due to periodic erosion and establishment of invasive species such as the *Cakile edentula*. Common seashore species recorded some ten or twenty years ago such as *Spinifex sericeus* and *Ipomoea pes-caprae* are no longer common.
5. Recruitment of *Casuarina* seedlings along the island shores was relatively uncommon.

Soils

1. Soils of the Capricornia Cays were distinct for different land forms: seashore sands, beach ridge soils, interior soils and glades. Soil development patterns were similar to Coringa-Herald Cays. However, nutrient levels on Capricornia Cays were well below levels recorded for Coringa-Herald Cays for similar landforms (Batianoff et. al., 2008a).
2. The most nutrient-rich soils were from *Pisonia grandis* forested areas. Formation of peat occurred on Masthead and North West Islands. In these areas, a compact layer of rich humus up to 12cm deep formed on the surfaces.
3. Where there is death in Pisonia forests, there was a release of nutrients into the soils, followed by rapid leaching, evidenced by the lower nutrient concentrations from glade areas as compared to intact forest stands.
4. The Ficus and Celtis rainforest patches on Tryon Island had high levels of soil nutrients.

Climate trends

1. The maritime climate of the Capricornia Cays is moderate. Temperatures do not get as low or as high as on the adjacent mainland. The rainfall is more evenly distributed throughout the year than in the tropics.
2. A historical increase in ambient temperature of around +1.0ºC since 1958 was recorded for summer maximum temperatures (R^2=0.79) and annual maximum temperatures (R^2=0.97). There was a weaker increase in summer minimums and no significant change in winter temperatures.
3. There was a strong trend detected for longer droughts (less mean rainfall) from 3–4 years in the 1940–1991 period to 3–7 years in the period 1992–2007.

Seabirds

1. A variety of tropical seabirds visit and/or breed on the Capricornia Cays, e.g. lesser frigatebirds, *Fregata ariel* and red-tailed tropicbird, *Phaethon rubricanda*.
2. Birds, both seabirds and forest birds, e.g. doves, are important for the dispersal of many plants including rainforest species and weeds with fleshy fruits.

Management recommendations

1. The use of indigenous species for landscaping / gardens around resorts, camping grounds and other inhabited areas is recommended (see Appendix D).
2. The early detection and responsive control of new incursions of weeds and exotic invertebrates such as scale insects and ants should be a high priority.
3. Weed control on all islands should remain a high priority, with the most severe infestations occurring on the islands with the highest human visitation.
4. Disseminate quarantine information to all visitors to the Capricornia Cays.

5. Continue to monitor the vegetation and flora to quantify changes due to management activities, visitor use patterns and climate variability.
6. Provide wildlife identification guides to visitors and island staff to improve appreciation of native wildlife.

PART A. BACKGROUND

1 Introduction

1.1 Background to the project

Large populations of seabirds and marine turtles, high plant diversity and the large areas of *Pisonia* community make the Capricornia Cays a globally significant and critically important area for conservation. The current management plans for the Capricornia Cays National Park and Capricornia Cays National Park (Scientific) state that conservation and recreational uses both require efforts to maintain natural and economic values (QPWS, 2000). In order to do this job effectively Queensland Parks and Wildlife (QPWS) engaged the Queensland Herbarium to update regional floristic, vegetation and regional ecosystems information for the Capricornia Cays.

Surveys of vegetation communities and regional ecosystems of the Capricornia Cays commenced in August 2007. Surveys were completed at North Reef Island, Tryon Island, North West Island, Wilson Island, Wreck Island, Heron Island, Erskine Island, and Masthead Island in 2007 over three separate field surveys. Lady Elliot Island was surveyed in March 2008. One Tree Island, the Hoskyn Islands, the Fairfax Islands and Lady Musgrave Island were surveyed throughout September 2008.

Though not part of the Capricornia Cays National Park or Capricornia Cays National Park (Scientific), North Reef Island and Lady Elliot Island have been included in this study. The inclusion of these islands contributes to a more comprehensive understanding of the island ecosystems in the region. Collectively, this report refers to all of the vegetated islands listed above that form the Capricorn-Bunker Islands as the Capricornia Cays.

1.2 Aims of the project

1. The project had the following outputs and outcomes:
2. Detailed baseline maps of island vegetation (1:3000 to 1:6000)
3. Detailed descriptions and maps of vegetation communities and Regional Ecosystems (REs)
4. Improved capacity to detect environmental stressors of plant communities including invasive weeds and pest insects.
5. Increased knowledge and understanding of the coral cay flora, plant communities and forest ecosystems including soil nutrition requirements.
6. Improved effectiveness of management to protect the values of coral cays in central Queensland, in particular *Pisonia grandis* dominated communities.

1.3 History of past research

The Capricornia Cays have been the subject of numerous surveys (Table1.1). The flora of several islands have been reported individually, e.g., the terrestrial vegetation survey of Tryon Island (Cribb, 1979), Masthead Island (Batianoff, 1999), Wilson Island (Batianoff and Hacker, 2000). Many islands were visited as part of regional flora surveys, e.g., MacGillivray & Rodway (1931); Heatwole (1984a) and Chaloupka & Domm (1985). Vegetation reporting has been confined to general descriptions (e.g., Domm, 1971; Flood, 1977; Heatwole, 1984b). Aspects of geomorphology were studied by Flood (1977; 1984). Comprehensive bird reports are available, some that include brief descriptions of the vegetation (Hulsman, 1984; Walker & Domm, 1986). The ecological factors affecting the number of species have been reviewed by Heatwole (1976). Factors affecting weed incursions at Capricornia Cays have been discussed by Chaloupka & Domm (1986), Batianoff (1998 & 1999a) and Heatwole & Walker (1989).

Table 1-1. List of publications and reports for individual islands

Coral cay	Historical research
North Reef	Walker & Domm (1986): Walker & Ogilvie (1988).
Tryon	Cribb (1979)
North West	Cribb (1969); Cribb (2005); Jahnke (2005)
Wilson	Cribb (1965); Batianoff & Hacker (2000)
Wreck	Nil known
Heron	Fosberg & Thorne (1961); Gillham (1963); Cribb (1976); Rogers (1989) Rogers & Morrison (1994);
Erskine	Nil known
One Tree	Heatwole *et al*. (1981)
Masthead	Longman (1914); Edgell (1929); Cribb (1975); Batianoff (1999a)
Hoskyn Islands	Cribb (1972)
Fairfax Islands	Cribb (1986)
Lady Musgrave	Elsol (1985); Walker (1991b)
Lady Elliot	Batianoff (1998); Walsh (1987)

2 Physical environment

2.1 Regional setting

Straddling the Tropic of Capricorn, the Capricorn-Bunker region of the Great Barrier Reef (GBR) Marine Park is located on the western side of the marginal shelf at the southern end of the GBR (QPWS, 2000). Forming a geomorphic province distinct from the rest of the GBR (Hopley, 1982; QPWS, 2000), the Capricornia Cays archipelago features one of the highest concentrations of coral cays on the GBR (Hopley, 1982; King, 1993; QPWS, 2000). The Capricornia Cays lie between 45 and 75 km off the central Queensland coast (Figure 2-1. Locality map of the Capricorn and Bunker island groups within the Capricornia Cays in the southern Great Barrier Reef. The 15 vegetated cays of the Capricornia Cays range in size from about 4 ha to 107.3 ha with elevation ranging from 3 metres to 9 metres. Island substrates are either sand, shingle or a mixture of the two (Flood, 1977), though the classification of island substrate is sometimes disputed (Mather & Bennett, 1984). The cays are around 5000 years old, having developed during the Holocene period (QPWS, 2000). All of cays excepting the shingle cays are located on leeward margin of reef tops ranging from 1 km^2 to 28 km^2 (Mather & Bennett, 1984).

The Capricornia Cays National Park and the Capricornia Cays National Park (Scientific) form part of the Mackay/Capricorn Management Unit in the Great Barrier Reef Marine Park Authority (GBRMPA). The zoning of the islands ranges from the Habitat Protection Zone (‘blue’) to the Scientific Research zone (‘orange’).

The Capricornia Cays are separated from the mainland by the Curtis Channel (QPWS, 2000), and have distinct currents operating in the region. The South Equatorial Current (SEC) reaches the GBR at about 14ºS of the equator, where it splits in to the Hiri current running northwards along the continental shelf, and the East Australian Current (EAC) running southwards (Wachenfeld *et al*., 2007). The SEC and EAC operate to give the Capricornia Cays flora more of an affinity with the islands of the Coral Sea than of the mainland of Australia (Batianoff & McDonald, 1980; QPWS, 2000). According to the bioregionalisation of the GBR, the Capricornia Cays area is oceanographically isolated and may be biologically distinct from the rest of GBR. Domm (1971) also recognised this as a distinct province within the GBR.

The Far North area of the GBR also features a large number of coral cays (King, 1993); however, very few coral cays are located in the central sections of the GBR. This separation of the northern and southern coral cays highlights the importance of studying the Capricornia Cays as a distinct unit of islands within the GBR, particularly as they are the southernmost cays in the GBR and Australia. Recently this has been recognised as a separate subregion Southern Great Barrier Reef Subregion (12.11) within the Southeast Queensland bioregion.

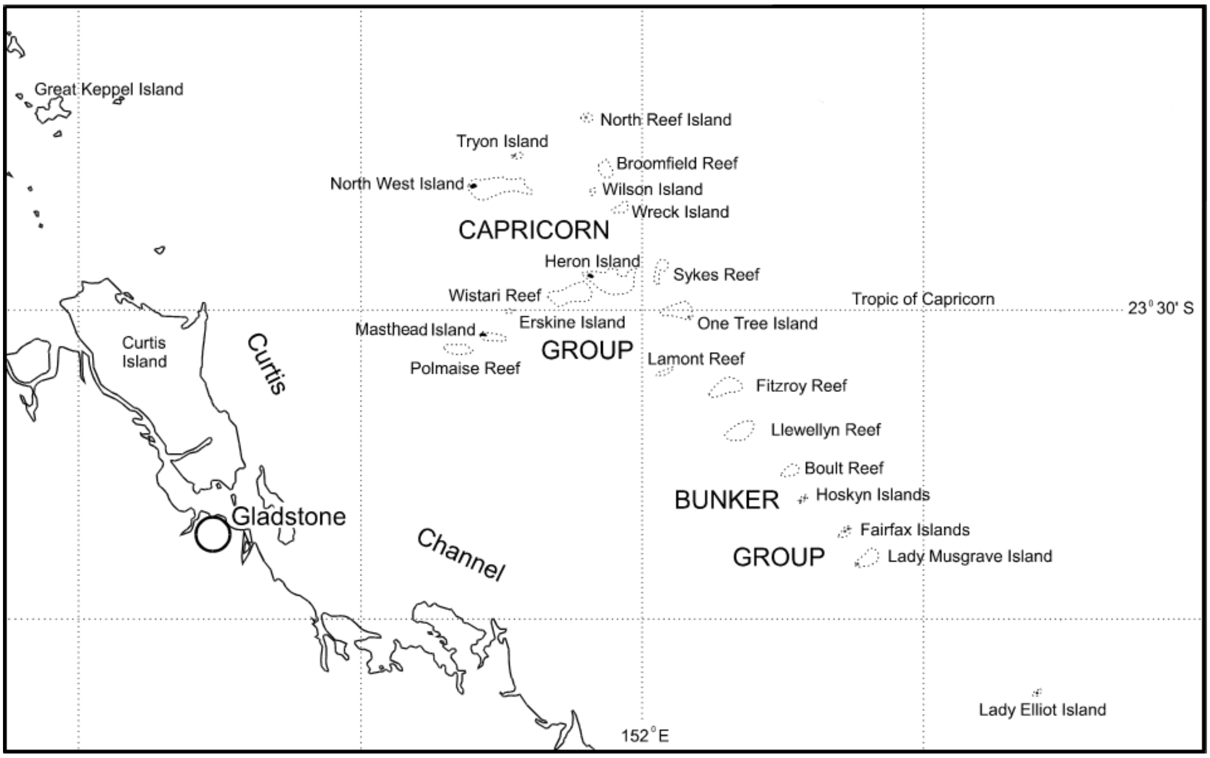


Figure 2-1. Locality map of the Capricorn and Bunker island groups within the Capricornia Cays in the southern Great Barrier Reef.

2.2 Island descriptions

2.2.1 North Reef Island

North Reef Island (23º11'S, 151º54'E) is the northernmost Capricornia Cay. This Commonwealth Island is not formally part of the Capricornia Cays National Park or National Park (Scientific); however, it is managed on a day-to-day basis by QPWS. The island is oblong in shape, measuring approximately 300 m across the E-W axis, and 100 m across the N-S axis. Currently, a sand spit extends from the western point of the island. Heatwole (1984a) recorded the island's area at about 4.5 ha with a vegetated area of 0.5 ha. Currently, the island's area is estimated at around 3.45 ha, with a vegetated area of 1.7 ha. As noted by Flood (1977), this cay is highly dynamic. The maximum elevation is about 2-3 m above MSL.

A lighthouse with a basal diameter of around 12 m was built in 1878. The lighthouse was attended by live-in light-keepers until 1978, and currently operates automatically. Disturbance to native vegetation was evident from the presence of weeds and the planted coconut trees around the base of the lighthouse. Much of the originally cleared areas have since been reclaimed by native shrubs and small trees of *Scaevola taccada* (0.27 ha) and/or *Argusia argentea* (0.41 ha). The current vascular flora consists of 16 species, including 12 indigenous and 4 exotic species. Two or three *Pisonia grandis* trees were found growing in the middle of the cay.

2.2.2 Tryon Island

Tryon Island (23º14'S, 151º49'E) is an elongated sand island that is about 725 m long and 50 m wide. Its long axis is orientated roughly NE to SW. It features an elevated sand ridge (about 10 m high) that runs about halfway along the south-western side of the island. The south-western end of the sandy beach is buffered by an extensive beach rock platform. Smaller pockets of beach rock areas were found at the north-eastern end of the island. A sand spit extends for about 50 m from the north-western end of the island. The area of the island has been previously estimated at 14 ha (QPWS, 2000) with a vegetated area of 7 ha (Heatwole, 1984a). The current area is estimated as 15.26 ha with a vegetated area of 10.04 ha. It is probable that the island was mined for guano in the late 1890s but the effects of mining were not obvious.

The island features areas of *Pisonia grandis* open to closed-forest (currently 1.4 ha, formerly estimated to cover 4.2 ha) which have undergone deforestation due to scale insect infestations (Kay *et al*., 2003). Since the loss of Pisonia, the central area of the western end has been colonised by herbaceous weedy species (2.87 ha), as well as planted *Pisonia* cuttings. Public use of the island is currently restricted. It was used for camping up until 1990. For its size Tryon island supports a high diversity of flora. The rainforest species present include *Ficus* spp., *Celtis paniculata* and *Pipturus argenteus*. It is the only island in region with *Ximenia americana*. The current vascular flora consists of 38 species, including 26 indigenous species, 11 exotic species and one mainland native.

2.2.3 North West Island

North West Island (23°18'S, 151°42'E) is the largest Capricornia Cay. The island is oblong-shaped, about 1850 m long and 850 m wide. It is oriented roughly E to W. The island's area is 119.8 ha, although it has been reported as 150 ha by Jell & Flood (1978) and 153 ha by the GBRC (1977). The vegetated area was reported as 90 ha by Flood (1984), but is currently estimated as 107.3 ha. The island is composed of sand (Domm, 1971), with small areas of exposed beach rock extending from the eastern end. A permanent camping ground which has capacity for 150 campers has been established at the north-western side, with interpretative displays, shelter and storage sheds and three toilet blocks. A walking track runs S-SE from the camping ground to the southern side of the island.

Evidence of former human activities includes two piles of broken phosphate rocks, remains of guano / phosphate rock mining from 1891-1900, towards the centre of the island along the main walking track (Table 2-1). Heatwole (1984a) suggests that North West Island is the most disturbed of the uninhabited Capricornia Cays. However, the areas visibly affected by the phosphate rock mining are relatively small (Heatwole, 1984a). Other historic disturbances include the turtle soup-canning factory that operated in the early 1900s, and the introduction of goats, feral fowls, domestic cats, rats, mice, and some plants and insects (Heatwole, 1984a). According to J. Olds (pers. obser., 2007), some *Celtis paniculata* seeds were dispersed by the feral fowl. The current vascular flora consists of 47 species, including 33 native species, 13 exotic species and one mainland native. The interior of the island was dominated by *Pisonia grandis* open to old-growth closed-forests (89% of vegetated area, 96.2 ha).

2.2.4 Wilson Island

Wilson Island (23°18'S, 151°55'E) is one of the few mixed sand/shingle Capricornia Cays (Heatwole, 1984a). The island is roughly circular about 340 m wide and 250 m long with an extensive sandy beach extending from the western shore. Large coral rubble fragments litter the sandy beaches. The eastern shore is buffered by a continuous, solid beach rock wall of loose beach rock rubble. The island's area was estimated at 12 ha (Jell & Flood, 1978), and 7 ha by the GBRC (1977) and QPWS (2000). The current estimate is 7.78 ha. The vegetated area was about 3.5 ha in 1980 (Flood, 1984) and is currently 4.01 ha. According to Flood (1984), Tropical Cyclone 'Simon' added a considerable volume of sediment to the north-western beach. He also mentions that the beaches on Wilson Island are exceptionally mobile and tend to migrate back and forth over several metres. Maximum elevation is about 3-4 m. The island lies west of its reef centre (Heatwole, 1984a).

Wilson Island features about six small huts that are operated by the current resort leaseholders of Heron Island. Other related infrastructure includes bathrooms, a kitchen/dining area, pathways and a septic system. The interior of the island features *Pisonia grandis* stands (1.2 ha) that were recently (2006/07) affected by pest scale insect (*Pulvinaria urbicola*) outbreaks. A biological control program using the predatory ladybeetle *Cryptolaemus montrouzieri* was effective in controlling the scale insect and retaining tree cover (Olds, pers. comm., 2006). The current vascular flora consists of 27 species, including 18 indigenous species and nine exotic species.

2.2.5 Wreck Island

Wreck Island (23º 19'S, 151º 59'E) is an elongated, oval-shaped sand island. However, Heatwole (1984a) recorded some shingle components. Its long axis is about 750 m long, oriented approximately SW-NE. The widest part of the island is towards the SW end, measuring about 150 m. A sand spit extends about 150 m from the edge of the vegetation on the NE tail. A field of pumice is visible, during low tide, to the north of this sand spit. The total island size has been estimated at between 7 and 14 ha with a vegetated area of 4 ha (Heatwole, 1984a). The current estimate is 10.08 ha with a vegetated area of 5.67 ha. A steeply sloping (30º) vegetated ridge (about 5 m) runs along the south-eastern shore forming a 'backbone' to the island. A discontinuous line of beach rock extends along the south-eastern shore.

Evidence of historic land uses include remnants of a shack within the central *Pisonia grandis* closed-forest (0.94 ha) that was used by researchers conducting turtle monitoring. Other known uses include oil exploration (QPWS, 2000). The current tenure of Wreck Island limits visitation to QPWS staff and other permitted visitors. The current vascular flora consists of 23 species, including 19 indigenous species, three exotic species and one mainland native.

2.2.6 Heron Island

Heron Island (23°26'S, 151°57'E) is a sand island measuring about 750 m long and 125 m wide. Oblong in shape, the long axis is oriented approximately E to W. The island's area has been estimated at between 12 and 29 ha (Heatwole, 1984a) and 17 ha (QPWS, 2000); the current estimate is 22.07 ha with a vegetated area of 9.89 ha which is reduced from the 13 ha in 1980 (Flood, 1984). The perimeter of the island features continuous beach rock platforms along the south-eastern and north-western shores, with sandy beaches surrounding the north-eastern and south-western ends. The maximum height is about 3-4 m.

About 32% of the western side of the island is covered by the Heron Island Resort, the University of Queensland Research Station, and Queensland Parks and Wildlife infrastructure. Within the developed areas are numerous lodgings for tourists and staff, as well as other resort-related infrastructure such as dining areas, shops, a tennis court, swimming pool, rubbish dump, a water desalination plant, interpretative displays, garden areas and walking paths. Housing and buildings for QPWS rangers living on the island are located towards the middle of the island. A harbour and a helipad have been constructed at the western end. A retaining wall has been constructed around the north-western side. Evidence of a former turtle canning station is located towards the central northern shore. *Pisonia grandis* stands cover 6.23 ha, 63% of the vegetated part of the island, with some large remnant individuals within the resort grounds. The current vascular flora consists of 55 species, including 24 indigenous species, 31 exotic species and one mainland native.

2.2.7 Erskine Island

Erskine Island (23º 30'S, 151º 08'E) is an oval-shaped sand island measuring approximately 260 m long by 100 m wide. The long axis is oriented approximately SW-NE. The island's area has been estimated at between 2 and 6.5 ha with a vegetated area of 1.5 ha (Heatwole, 1984a; QPWS, 2000). The current estimated area is 5.02 ha with 1.8 ha being vegetated. The island features wide and relatively steep beaches that surround the entire island (Heatwole, 1984a). Isolated pockets of beach rock that are visible at low tide are scattered along the northern and eastern sides. The central area is relatively flat and has a maximum elevation of around 5 m.

Erskine Island is relatively free of human disturbance. Of the vegetated area, only 10% was dominated by *Pisonia grandis*; however, other woody species include *Celtis paniculata*, *Ficus opposita* and *Argusia argentea* (33% of area). The current vascular flora consists of 21 indigenous species and one exotic species.

2.2.8 Masthead Island

Masthead Island (23º 32'E, 151º 43'S) is the second largest island in the Capricornia Cays (49 ha). Heatwole (1984a) estimated its vegetated area at 32 ha, compared to the current estimate of 35.5 ha (44.25ha total area). It is the closest island to the mainland. The island is composed mainly of sand with a maximum elevation of 3-4 m. The island is roughly oblong-shaped measuring about 1400 m by 400 m with the long axis aligned approximately E–W. The cay is situated on the western end of a long narrow reef (7 km^2) that does not feature a lagoon area. A continuous platform of beach rock borders the shoreline for approximately half the exposed southern side of the island. Beach rock on the north-western end is less extensive and is presently covered by sand. A beach ridge rising 1-2 m runs along the southern shoreline and is highest in elevation approximately halfway along the shore. Despite the buffering by the beach rock platform, the southern shore currently has been undergoing erosion, evident by the loss of trees from the shoreline ridge vegetation.

Masthead Island has been used for camping for many decades. The current capacity is capped at 50 persons. There are no toilet facilities provided. *Opuntia stricta* was reported as well established by Mather & Bennett (1984). The current population of *Opuntia* is reduced to few small pockets. Heatwole (1984a) mentions the camping and cutting of *Casuarina* timber by Japanese sailors before the Second World War. There appears to be no significant deposits of phosphate rock or guano and no evidence of mining has been detected. One of the early explorers, Steers (1938) described this island as the most attractive in the area because of the thick and luxuriant covering of *Pisonia grandis* forest (27.98 ha; 78.8% of the vegetated area). Heatwole (1984a) lists this island as one of the nine most important areas for seabirds within the Great Barrier Reef. Batianoff (1999a) considers that Masthead Island has retained most of its natural values and has had less human impact than other nearby *Pisonia* covered islands (i.e., North West Island, Heron Island). The current vascular flora consists of 42 species, including 36 indigenous and five exotic species and one mainland species.

2.2.9 One Tree Island

One Tree Island (23°31'S, 152°08'E) is a shingle cay (Mather & Bennett, 1984), about 5.55 ha in area with 3.81 ha being vegetated and is shaped like a thick boomerang. In contrast to other cays in the region, the cay is on the weather side (southeast) of the reef, comprised largely of ridges of coral shingle and has a brackish pond near the centre (Mather & Bennett, 1984). There are several small, unstable, shifting rubble banks on outer edge of One Tree Reef. Mather & Bennett (1984) recorded an eroding cement pavement of reef-front corals windward of the cay which merges into beach rock along the western shore. A research station for the University of Sydney was built in 1971 and is located towards the north-western corner. The station accommodates up to 10 visiting scientists with permanent care takers. The island has restricted access as it is part of the Capricornia Cays National Park (Scientific).

According to Heatwole (1984a) *Rhizophora stylosa* was growing in the brackish pond. No mangroves were found in this survey. The current vascular flora consists of 28 species, including 20 indigenous and eight exotic species.

2.2.10 Hoskyn Islands

The two Hoskyn Islands (23° 48'S, 152°18'E) belong to the Capricornia Cays National Park (Scientific). Little information on land use history has been found in the published literature. Heatwole (1984a) and Flood (1977) classify Hoskyn (West) Island as a sand island with some coarse coral shingle conglomerates on the eastern shore and beach rock on the western shore. It is elongated in shape, with the long axis slightly west of N-S. The island is 9.48 ha in area with 6.41 ha vegetated, The island measures approximately 650 m in length and 200 m in width. It lies on the south-eastern edge of a 3 km^2 closed-ring reef (Flood, 1977). The current vascular flora of the western island consists of 24 species, including 20 indigenous and four exotic species.

The East island is the smaller of the two Hoskyn Islands, lying north-east of the centre of the reef. Hoskyn (East) is 2.35 ha (1.58 ha vegetated) in area and measures about 280 m in length and 100 m in width. This oblong island is composed of coarse coral fragments arranged in ridges, with its long axis oriented northeast-southeast. Flood (1977) considers it to be a shingle island. It has a deep soil containing guano (Heatwole, 1984a). The current vascular flora consists of 20 species, including 15 indigenous and five exotic species.

2.2.11 Fairfax Islands

The Fairfax Islands (23° 51'S, 152°22'E) are situated on a 4 km^2 reef. They form part of the Capricornia Cays National Park (Scientific). The western island has been reported as having a sand and shingle substrate (Heatwole, 1984a) though Flood (1977) considered it a sand island. An elongated sand spit is located at the western end of the island. The island is approximately 500 m long and 220 m wide.

The area of the western island is 7.33 ha (4.26 ha vegetated) in area. The current vascular flora of the western island consists of 26 species, including 19 indigenous, six exotic species and one mainland native. The eastern Fairfax island is a shingle cay (Flood, 1977), measuring approximately 1110 m in length and 245 m at its widest point (eastern), the island is 21.21 ha (15.78 ha vegetated) in size, and tadpole-shaped. There is an extensive perimeter of beach rock around the island, especially at the western end. Two brackish pools, one much larger than the other, are located toward the eastern end of the island. The current vascular flora consists of 18 species, including 12 indigenous and six exotic species.

The Fairfax islands were mined for phosphate in the 1890s and later used as a bombing range by the Australian Navy (Heatwole, 1984a; QPWS, 2000). Goats were introduced to the islands and by 1936 had left no undergrowth at all. Goats were eradicated in the late 1980s (QPWS, 2000). Currently, the islands receive infrequent visitation by human visitors due to its restricted access zoning.

2.2.12 Lady Musgrave Island

Lady Musgrave Island (23° 54'S, 152°25'E) (LMI) is the second-most southern Capricornia Cay. Elsol (1985) estimated the island size as 14 ha; with a length of around 600 m. Walker (1991b) estimated the island size as 13 ha. The current estimate is 19.47 ha with 15.10 ha vegetated. Heatwole (1984a) describes the shape of LMI as irregular, and nearly-rectangular with its long axis oriented north-east to south-west. Descriptions of geology provided by Heatwole (1984a) and Elsol (1985) indicate that the island is composed predominantly of coarse coral fragments and some sand underlain by a bed of coral conglomerate (i.e., beach rock) which is visible at the eastern and northern shores. Flood (1977) considers this to be a 'shingle' island. Heatwole (1984a) describes a small brackish pond occurring towards the southern end of the cay. LMI is situated on the south-western edge of its surrounding 10 km^2 reef (Heatwole, 1984a).

Previous flora lists of the island have been provided by MacGillivray and Rodway (1931) from their 1927 collection (11 spp.), Heatwole (1984b), Elsol (1985) and Walker (1991b) from 1989. Specimens have also been collected by G. Batianoff (2000) and 52 species are represented in the Queensland Herbarium (32 collected by GNB). There are approximately four species per hectare. Elsol (1985) recognised 42 species. Walker (1991b) provides a comparative list of species, including cultivated species that were collected from each trip. There are 57 species on the list, but *Scaevola taccada* and *Wollastonia biflora* (currently frequent on LMI) are absent from the list (Walker, 1991).

In the 1890s, substantial areas of vegetation and soil were cleared for guano/phosphate-rock mining. In addition, the influence of goats that were introduced to the island by miners in 1898 also contributed to vegetation removal. Walker (1991b) reports the vegetation as being "stripped bare". Daly and Griggs (2006) describe ridges that resulted from the removal of guano, based on observations made during the geographical survey by Steers in 1936. This altered landscape was more visible following the removal of vegetation by goats (Daly & Grigg, 2006). By 1927, there were 23 goats per hectare (Walker, 1991b). By 1936 their numbers had been reduced and the vegetation was recovering. The last of the goats were removed in 1974 (Flood, pers. comm., cited in Heatwole (1984a).

A resort was in operation during the 1930s. All that remains is a concrete slab (QPWS, 2000). Between 1984 and 1989, tourist numbers rose eight-fold, and LMI is now considered to be the sixth most heavily visited island on the GBR (Walker, 1991). Its proximity to the mainland (~60 km) means its visitation is higher than other islands in the Capricornia Cays NP, and it is the most intensively used for camping. The camping capacity is capped at 40 persons. In 1997, more than 10,000 day-visitors were brought by commercial tourist vessels. In addition, 1278 campers spent 8008 camping nights and around 5840 visitors from recreational boats used LMI (QPWS, 2000). Campground toilets are also present.

LMI is considered one of 14 most important breeding sites for birds on the GBR (Heatwole, 1984a). More than 20,000 seabirds (WTSW, BN) nest on the cay during summer with partial displacement by tourists of less abundant ground-nesting terns (Walker, 1991). *Pisonia* forests (11.13 ha) cover 73.7% of the vegetated part of the island. The current vascular flora consists of 39 species, including 20 indigenous, 18 exotic species and one mainland native.

2.2.13 Lady Elliot Island

Lady Elliot Island (24º06'S, 152º43'E) is the most southern of the GBR islands. Situated about 80 km NE of Bundaberg, (LEI) lies about 10 km west of the edge of the continental shelf, and is surrounded by waters up to 40 m deep (Walsh 1987). The Island is 42.40 ha (32.86 ha vegetated) in area, roughly rectangular in shape, the long-axis is oriented NE – SW. The island is composed of near-concentric shingle ridges composed of coral, *Tridacna* shells and bioclastic sand bound by guano-derived phosphatic cement (Chivas *et al*., 1986). The beach rock is most prevalent on the windward SE side.

The vegetation has been extensively modified by guano-mining. The operation resulted in the removal of virtually all of topsoil (1–2 m) (Heatwole 1984a, Hopley 1982, Daly & Griggs 2006). Currently, the island is highly modified with a resort, lighthouse, air strip, staff quarters and many garden and lawn areas. The current vascular flora consists of 97 species, including 21 indigenous, 66 exotic species and ten mainland natives.

2.3 Land use history

The Capricornia Cays and their surrounding reefs are some of the most heavily utilised areas in the Great Barrier Reef (QPWS, 2000). There is limited knowledge about the use of the coral islands by Aboriginal people prior to European settlement. Historic human use of the islands since the late 1800s included navigational lighthouses, guano and phosphate rock mining, turtle canneries, and military training (QPWS, 2000; Daly & Griggs, 2006). Currently, the islands are used for a range of commercial and recreational activities including resorts, camping, fishing, educational research stations, recreational boating, scuba-diving, and snorkelling The extent of habitat modification that is evident on the islands today varies from the heavily modified Lady Elliot and Heron Islands, to the relatively undisturbed Erskine Island.

The most extensive degradation resulting from guano mining occurred at Lady Elliot Island, where several metres of topsoil and most of the vegetation were removed for the mining of high-grade guano (Daly & Griggs, 2006). North West Island was also extensively mined and has been reported as the most extensively disturbed of the uninhabited Capricornia Cays (Heatwole, 1984a). Steers (1938) reported ridges on Lady Musgrave Island that resulted from the removal of guano, and noticeable erosion of North West Island also linked to the removal of guano (Daly & Griggs, 2006). Animals such as domesticated fowls and goats were introduced during guano mining operations (Daly & Griggs, 2006).

Table 2-1. Details of island features and known disturbance history for each Capricornia Cay

Coral cay	Veg (ha)	Reef (km^2)	Substrate	Historic Land use	Current land use	DL
North Reef 3.45 ha	1.7	2.5	Sand	Lighthouse/weather station; permanently manned until 1978, with planted gardens and storage sheds. Feral cats.	Low visitation, maintenance of automated BOM weather station and lighthouse.	30%
Tryon 15.26 ha	10.04	2.0	Sand	Moderately high level of camping use until 1990. Probably also mined for guano from 1898-1900.	No camping; rehabilitation following loss of *Pisonia* forest during late 1990s. Volunteer weeding programs, revegetation trials of *Pisonia grandis* plantings.	40%
North West 119.8 ha	107.26	38.0	Sand	Guano / rock phosphate mining from 1891-1900, turtle-soup canning factory around 1910 and 1924. Feral fowl, domestic cats, rats, mice and some introduced plants and insects.	High levels of seasonal camping; 3 toilet blocks, interpretative displays, storage facilities.	50%
Wilson 7.78 ha	4.01	1.0	Sand/ shingle	Moderate level of visitation and camping.	Camping resort with a number of buildings.	50%
Wreck 10.08 ha	5.67	4.0	Sand	Low visitation, oil exploration one private residence in late 1960's, rats.	Current – low visitation.	25%
Heron 22.07 ha	9.89	27.0	Sand	High visitation, > 15% of land supports buildings for research stations and resort.	High visitation, > 10% of land supports buildings for research stations and resort.	60%
Erskine 5.02 ha	1.80	1.3	Sand	Past – low visitation.	Current –low visitation.	20%
Masthead 44.25 ha	35.5	7.0	Sand	Moderately high camping.	Seasonal camping with no permanent buildings.	30%
One Tree 5.55 ha	3.81	14.0	Shingle	Australian Museum leased reef in 1969, began building research station in 1971.	Sydney University research station.	30%
West Hoskyn 9.48 ha	6.41	3.0	Shingle	Past – low visitation; possibly used for guano-mining.	Current – low visitation.	20%
East Hoskyn 2.35 ha	1.58	3.0	Sand	Past – low visitation; possibly used for guano-mining.	Current – low visitation.	20%
Fairfax (West) 7.33 ha	4.26	4.0	Sand, shingle	Past – guano / rock phosphate mining, bombing-range, goats, rats.	Current – low visitation.	30%

Coral cay	Veg (ha)	Reef (km^2)	Substrate	Historic Land use	Current land use	DL
Fairfax (East) 21.21 ha	15.78	4.0	Shingle	Past – guano / rock phosphate mining, bombing range, goats, rats.	Low visitation.	40%
Lady Musgrave 19.49 ha	15.10	10.0	Shingle	Light tower, guano / rock phosphate mining, camping, high visitation, resort during 1930s.	Current – high level of visitation, seasonal camping, toilet block.	60%
Lady Elliot 42.40 ha	32.86	1.8	Shingle	Lighthouse, high level of guano / rock phosphate mining, >90% of top soil removed, active replanting in 1960s.	Lighthouse, resort buildings and air strip; high level of visitation; > 10% of the cay is used for human occupancy.	90%
Total area: 335.55 ha	**255.68**	**122.6**				

Sources: Heatwole (1984b); QPWS (2000); Daly & Griggs (2006). **DL**: Disturbance level

2.4 Climate

The Bureau of Meteorology (BOM) currently operates two weather stations within the Capricornia Cays: Heron Island (Station No. 039122, est. 1956) and Lady Elliot Island (Station No. 39059, est. 1939). Weather data has also been recorded from North Reef Island (Station No. 039130) from 1962–1977. The general climate character for the Capricornia Cays has been extrapolated from ambient temperature, rainfall, humidity and wind data recorded from these weather stations (BOM, 2008a). Information on cyclonic activity in the region has also been provided by BOM (2008b). The data analysed were accurate up to the 16th of December 2008 (BOM, 2008a; 2008b). Unless otherwise stated, all references to seasons are to the standard allocation of months, i.e. summer is from December – February, autumn is from March – May, winter is from June – August, and spring is from October – November. All graphs presented have been derived from BOM data provided online (http://www.bom.gov.au).

Comparisons with the climate experienced at the adjacent coastal mainland (Gladstone, Pacific Heights), at Willis Island in the Coral Sea Islands Territory, and Lord Howe Island are highlighted. Mainland coastal weather stations were chosen based on proximity to the Capricornia Cays region and the length of records available. For instance, Pacific Heights was chosen instead of Yeppoon, as its period of recording is longer.

Reports of climate trends and patterns for the Great Barrier Reef have predominantly focussed on the broader region, with minimal attention given to local climate trends. As the Capricornia Cays are located at the southern end of the GBR, climate trends in this region are likely to differ from the general climate trends presented for the greater GBR region (e.g. Lough, 2007). Trends in climate extrapolated from the long-term data from the three Capricornia Cays weather stations are provided.

2.4.1 Ambient temperatures

Current

The Capricornia Cays experience a dry maritime climate that is generally warmer than the adjacent coastal mainland region. The ambient temperature range at Heron Island and Lady Elliot Island is from 16.6-29.5ºC (BOM, 2008a). Mean monthly temperatures for the region are given in Table 2-2. Winter is not as cold as on the mainland, with Gladstone recording a mean annual temperature range of 13.3-31.2ºC. Compared to other regions, the Capricornia Cays have a climate that is more similar to tropical regions than subtropical regions. Townsville has also recorded a similar range of 13.6–31.4ºC. The monthly temperature range for Willis Island in the Coral Sea is from 21.9–30.7ºC, while Lord Howe Island at the southern limit of coral reefs in Australia has a temperature range from 13.4–25.6ºC.

Mean monthly temperature at the Capricornia Cays is fairly consistent with a range of 12.6ºC between the warmest and coolest months. The temperature range is also consistent at Willis Island (8.8ºC), and Lord Howe Island (11.9ºC); however, mainland regions often have a higher range in temperatures (17.9ºC at Gladstone, and 17.8ºC at Townsville). The lowest temperature recorded at the Capricornia Cays was 5.0ºC at Heron Island in July 1965 (BOM, 2008a). The highest temperatures recorded was at Heron Island (34.7ºC) in December 2005.

Table 2-2. Climate averages for the Capricornia Cays, based on weather records from Lady Elliot and Heron Islands (source: BOM, 2008a).

	Ambient temperatures		Rainfall		Relative humidity (%)		Cyclones (1906-2007)	
Month	Min (ºC)	Max (ºC)	Mean (mm)	No. rain days	9 am	3 pm	No. recorded	% per month
Jan	24.1	29.5	113.1	8.7	74.0	70.0	4*	21.4
Feb	24.1	29.3	154.8	10.2	76.0	72.0	7*	35.7
Mar	23.5	28.5	117.7	10.3	74.5	71.5	8	33.3
Apr	21.9	26.8	107.9	10.6	73.0	70.0	1*	2.4
May	19.7	24.3	112.0	10.5	73.5	69.5	1	4.8
Jun	17.6	22.0	104.2	8.5	74.5	70.0	0	-
Jul	16.6	21.3	86.7	7.4	73.0	68.5	0	-
Aug	17.2	22.3	54.6	5.6	70.5	65.5	0	-
Sep	18.7	24.2	33.8	4.2	69.0	65.0	0	-
Oct	20.4	26.0	49.3	4.9	70.0	67.0	0	-
Nov	22.1	27.6	60.8	5.2	71.0	68.0	0	-
Dec	23.3	28.9	88.7	6.8	72.0	69.0	1*	2.4

Notes: * = cyclones recorded over both months

Trends

Long-term climate data available from Lady Elliot Island have shown an increase of around +1.0ºC in the maximum temperatures for all months since the 1958–1967 decade (R^2=0.97). Summer temperatures have also shown an increase for both the minimum (+0.6ºC, R^2=0.57) and maximum (+1.0ºC, R^2=0.79) temperatures since 1958 (Table 2-3). No significant trends have been detected for the winter temperatures. Long-term data from Heron Island is not complete so the robustness of this trend cannot be investigated. The average temperature increase in Australia over the last century is around +0.8 ºC, with minimum temperatures having risen at a greater rate than maximum temperatures (Hughes, 2003). Willis Island has recorded a greater increase in temperature during the winter months (Batianoff *et al*., 2008b, 2010a). The increases in maximum temperatures recorded indicate that the moisture stress may be increasing for wildlife, and evapotranspiration rates may be greater for plants (Korner, 2006).

Table 2-3. Ambient temperature changes for each decade at Lady Elliot Island

(Source: BOM, 2008a)

Period	Annual		Summer		Winter	
	Min	Max	Min	Max	Min	Max
1958-1967	20.5	25.2	23.3	28.5	20.9	25.4
1968-1977	20.6	25.4	23.4	28.6	20.1	24.8
1978-1987	21.0	25.6	24.1	29.3	20.3	24.7
1988-1997	20.7	26.1	23.8	29.8	20.4	25.1
1998-2007	20.8	26.2	23.9	29.5	20.4	25.0
Trend	**No trend**	**+1.0ºC (R^2=0.97)**	**+0.6ºC (R^2=0.57)**	**+1.0ºC (R^2=0.79)**	**No trend**	**No trend**

2.4.2 Rainfall

Current

Annual rainfall at the Capricornia Cays averaged 1035 mm over 85 rain days at Heron Island, and 1134 mm over 101 rain days at Lady Elliot Island. This gives an approximate mean rainfall for the region of 1085 mm over 93 rain days (Table 2-2). By comparison, the mean annual rainfall at the adjacent mainland towns ranged from 877 mm over 66 rain days at Gladstone, to 1302 mm over 72 rain days at Pacific Heights (BOM, 2008a). Mean annual rainfall at Willis Island (1115 mm) is similar to the Capricornia Cays whereas the more southerly Lord Howe Island mean annual rainfall is 1569 mm (BOM, 2008a).

The variance between the lowest annual rainfall and highest annual rainfall recorded on individual islands in the Capricornia Cays group (590–1924 mm) was not as high as Willis Island (241-2482 mm) (BOM, 2008a), which is most likely due to the higher number of cyclones experienced at Willis Island, bringing higher rainfall in shorter periods. The largest rainfall recorded in a 24 hour period in the Capricornia Cays was 454 mm at Lady Elliot Island on 31st January 1943.

According to Lough (2007), the climate at the Great Barrier Reef is dominated by two large-scale global circulation systems: the south-east trade wind circulation, and the Australian summer north-westerly monsoon circulations. In tropical regions, rainfall is usually highest during the monsoon season which corresponds with the summer to early autumn months in the southern hemisphere. The wettest month at the Capricornia Cays is February (150 mm) and September is the driest month (31 mm) (Figure 2-3).

Though mean annual rainfall amounts are similar for the Capricornia Cays and Willis Island, seasonal distribution of rainfall is more pronounced at Willis Island. About 65% of the rainfall received in the Capricornia Cays falls during the summer and autumn months of December - May. The equivalent period at the mainland receives around 72% of the annual rainfall. Winter rainfall accounts for 22% of rainfall at the Capricornia Cays and 11% at Willis Island (Figure 2-3). Rainfall at Lord Howe Island is more evenly distributed throughout the year, with winter rainfall accounting for 29% of the total (Figure 2-3). Average annual humidity for the Capricornia Cays is around 70-74%, which is less variable than Willis Island (68-81%). Lord Howe Island's relative humidity ranges from 60-70% (BOM, 2008a).

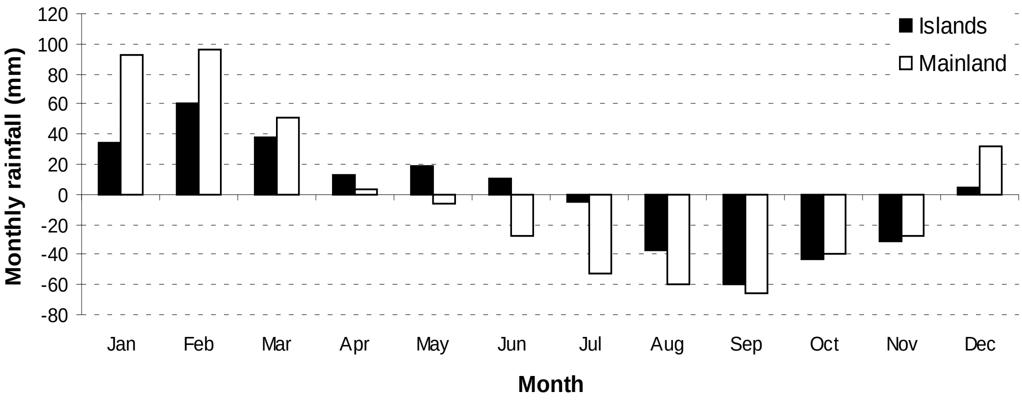


Figure 2-2. Comparison of average monthly rainfall of Lady Elliot, Heron Island and North Reef Islands in the Capricornia Cays, and coastal mainland locations of Pacific Heights, Gladstone and Bustard Head, compared with the mean monthly rainfall for the Capricornia Cays of 90.4mm per month.

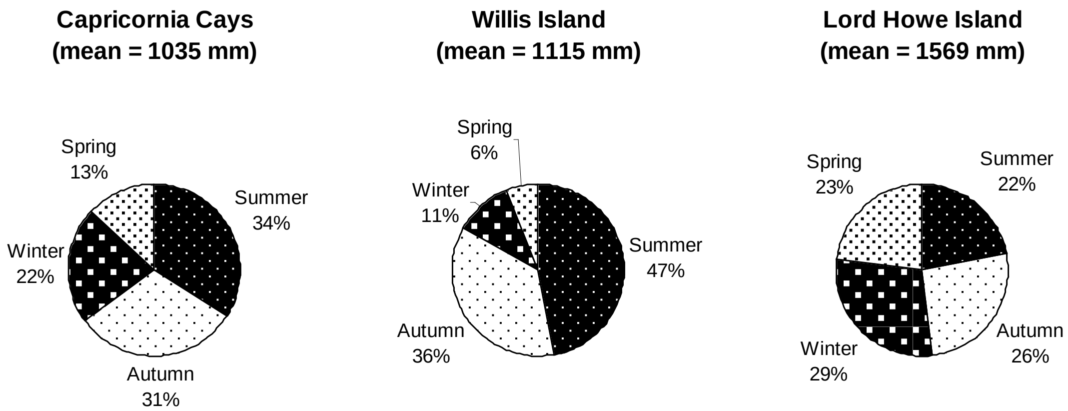


Figure 2-3. Comparison of rainfall seasonality at the Capricornia Cays, Willis Island and Lord Howe Island

Trends

Variability in annual rainfall is shown in Figure 2-4. Since weather recording began, annual rainfall has ranged from a minimum of 590 mm recorded at Lady Elliot Island in 2001 to a maximum of 1924 mm, also recorded at Lady Elliot Island in 1989 (BOM, 2008a). Throughout the Capricornia Cays region as well as Willis Island and Lord Howe Island, rainfall for the 15 years prior to 2007 has been lower than average, indicative of the recent drought across much of eastern Australia. Between 1993 and 2008 only two years had an above average rainfall at the Capricornia Cays, with similar accounts for Willis Island and Lord Howe Island (Figure 2-4). The major trend for duration of drought (less than the mean rainfall) has changed from three to four years (1940–1991) to three to seven years (1992-2007). In 2008-2011, Lady Elliot Island received average or above average rainfall (1029 to 1622 mm).

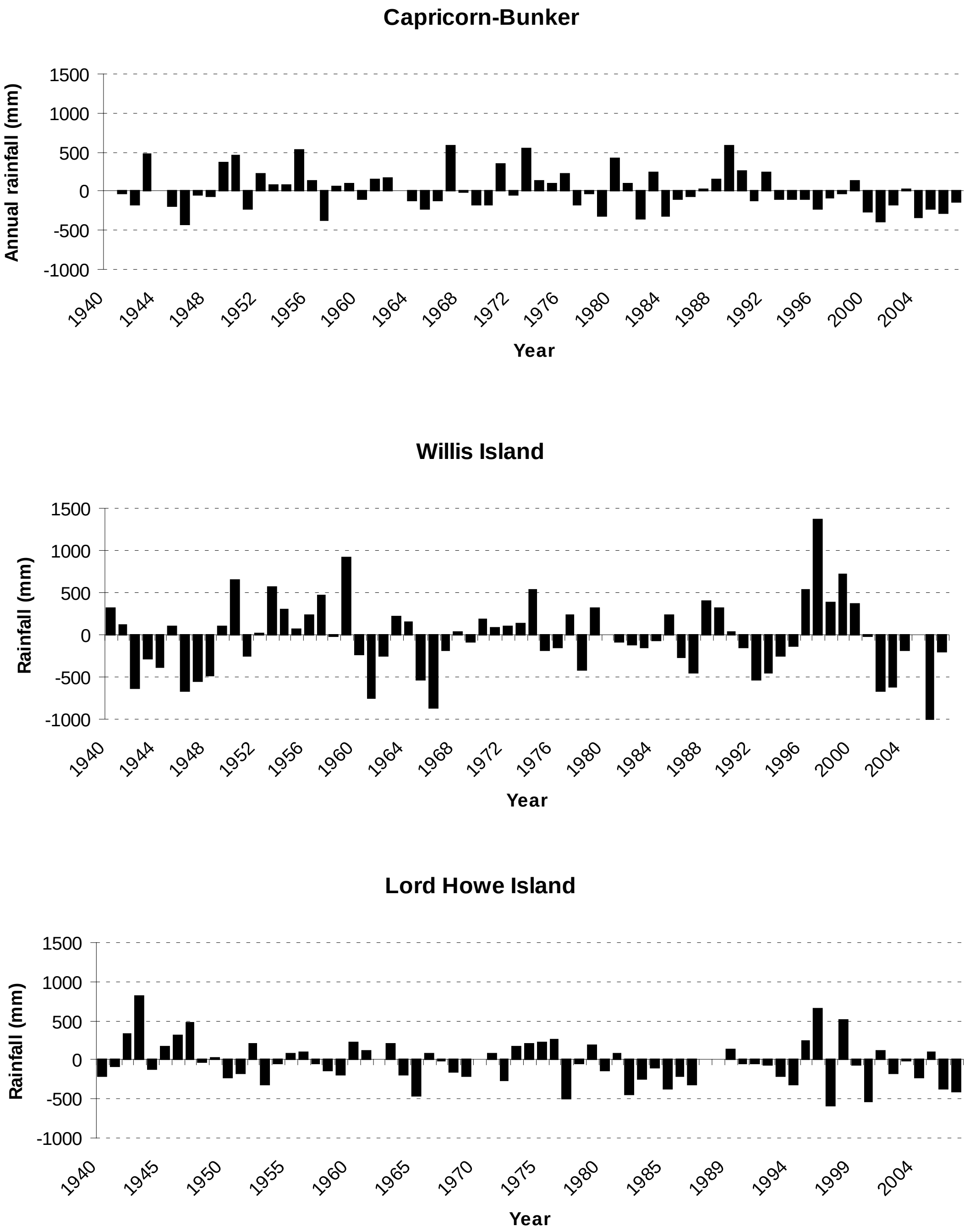


Figure 2-4. Long-term annual rainfall variability on the Capricornia Cays of North Reef, Heron and Lady Elliot Islands (top), Willis Island in the Coral Sea, and Lord Howe Island.

A change in the seasonality of rainfall is another climate change trend. During the 1940-1969 period summer rainfall accounted for 35.9% of all rain at Lady Elliot Island (Table 2-4). By the most recent 1980–2007 period, this proportion had decreased to 29.3%, a decrease of 6.6% (Table 2-4). During the same time, winter rainfall proportion has increased from 20.7% in 1940–1969 to 23.4% in the most recent 30-year period, an increase of 2.7%. Willis Island has also seen a decline in summer rainfall and an increase in winter rainfall, whereas Lord Howe Island's summer rainfall component has increased and winter rainfall decreased (Table 2-4).

Table 2-4. Seasonal proportion of rainfall at the Capricornia Cays, Willis Island and Lord Howe Island from 1940–2007

Location	Period	Summer	Autumn	Winter	Spring
Capricornia Cays	1940-1969	35.9	29.8	20.7	13.6
	1950-1979	34.5	28.6	21.9	15.0
	1960-1989	32.1	31.1	21.7	15.0
	1970-1999	30.6	32.1	22.0	15.3
	1980-2007*	29.3	33.0	23.4	14.3
	TREND	**-6.6%**	**+3.2%**	**+2.7%**	**+0.7%**
Willis Island	1940-1969	49.1	33.3	10.0	7.6
	1950-1979	47.9	35.1	9.8	7.2
	1960-1989	46.6	37.0	10.3	6.0
	1970-1999	43.5	40.0	11.2	5.4
	1980-2007*	44.6	38.9	11.8	4.7
	TREND	**-4.5%**	**+5.6%**	**+1.8%**	**-2.9%**
Lord Howe Island	1940-1969	21	25	30	24
	1950-1979	20	26	31	24
	1960-1989	19	26	31	24
	1970-1999	21	26	30	23
	1980-2007*	23	26	29	22
	TREND	**+2%**	**+1%**	**-1%**	**-2%**

2.4.3 Wind and cyclones

Current

Wind conditions on the Great Barrier Reef are relatively consistent throughout the year. The main wind influence is dominated by south-easterlies, especially during the 'dry' season from April to October. Calm conditions have been recorded for between 2–4% of the days (BOM, 2008a). The most variable wind conditions occur during the 'wet' summer season when the northerly monsoonal wind influence is most common (Wachenfeld *et al*., 2007).

At the Capricornia Cays, the least windy months are the spring months of September – November. The windiest months at 9am and 3pm are June/July and March, respectively (Table 2-5). Mean monthly wind speeds range from 17.0–24.6 km/h at Heron Island and 18.0–25.7 km/h at Lady Elliot Island (Table 2-5). Mean minimum wind speeds are similar at Willis Island, though the maximum speeds are greater. Lord Howe Island has a smaller range of wind speeds, with higher minimum wind speeds and lower maximum wind speed (Table 2-5).

Table 2-5. Wind conditions at Heron Island, Lady Elliot Island, Willis Island and Lord Howe Island (Source: BOM, 2008)

Wind speed (km/h)	Heron		Lady Elliot		Willis		Lord Howe	
	9am	3pm	9am	3pm	9am	3pm	9am	3pm
Mean wind speed	21.4	20.7	22.7	21.5	23.6	22.3	21.1	22.1
Mean minimum wind speed	17.7 Nov	17.0 Sep	19.5 Oct	18.0 Sep	18.8 Dec	17.2 Dec	19.8 Nov	20.7 Oct
Mean maximum wind speed	24.6 Jul	23.9 Mar	25.7 Jun	24.6 Mar	27.3 Apr/Jul	26.1 Jul	22.2 Jul	24.3 Jul

Cyclonic activity in the Capricornia Cays generally occurs in the period of January to March (Table 2-2). A cyclone was however recorded in the area in July 1935 (BOM, 2008b). Eight cyclones have passed within 50 km of Lady Elliot Island during 1906–2007, and 21 have passed within 100 km (BOM, 2008b). Nott & Hayne (2001) analysed the record of cyclones over the past 5000 years along the Great Barrier Reef and found that one extreme cyclone (i.e., with a pressure <920 hPa) occurred once every 200 cyclones recorded. Forty cyclones passed within 100 km of Willis Island, and nine within 50 km during the same period (BOM, 2008b). Fourteen have passed within 100 km of Lord Howe Island and three cyclones have passed within 50 km (BOM, 2008b).

Trends

Lough (2007) reports a decrease in the number of tropical cyclones in the Australian region overall from 1970-1997. However, whilst the frequency of cyclones overall has decreased, the frequency of intense cyclones has increased. Hughes (2003) also reports a slight decline in the number of tropical cyclones in the Australian region, but a slight increase in the number of more intense cyclones. There have been no clear trends towards an increase or decrease in cyclone frequency in the Capricornia Cays area since records started in 1906 (BOM, 2008b). Any spatial distribution changes in cyclone tracks will most likely be modulated by ENSO extremes (Lough, 2007).

3 Methodology

3.1 Fieldwork

Thirteen of the fifteen Capricorn-Bunker Islands were surveyed from August 2007 – September 2008 over five separate trips (Table 3-1). The two Hoskyn Islands were not visited during the 2007–08 surveys. However, the senior author surveyed the Hoskyn Islands in May 2000. The time spent on each island varied from two to three hours at the smaller islands to 7.5 days at North West Island.

Table 3-1. Dates of surveys of the Capricornia Cays: 2007-08

Trip No.	Islands	Start	End	No. of days
1 – Aug 2007	North West Island	18/08/2007	24/08/2007	7
2 – Sept 2007	North Reef Island	11/09/2007	12/09/2007	0.5
	Tryon Island	12/09/2007	14/09/2007	3
	Wreck Island	15/09/2007	16/09/2007	2
	Masthead Island	17/09/2007	19/09/2007	3
	Erskine Island	19/09/2007	19/09/2007	0.5
3 – Nov 2007	Erskine Island	16/11/2007	16/11/2007	0.5
	Heron Island	12/11/2007	14/11/2007	3
	Wilson Island	15/11/2007	15/11/2007	0.5
4 – April 2007	Lady Elliot Island	29/3/2008	1/4/2008	3
5 – Sept 2008	One Tree Island	23/09/2008	24/09/2008	2
	Lady Musgrave Island	19/09/2008	20/09/2008	2
	Fairfax Islands	21/09/2008	22/09/2008	1 day each
TOTAL				**29**

3.2 Flora

A list of all vascular plant taxa was compiled for each island. The frequency of each plant taxa was approximated as either ‘abundant’ (>25% cover), ‘frequent’ (6-25%), ‘infrequent’ (1-5%) or ‘rare’ (<1%) as per Batianoff and Burgess (1993). For analytical purposes, frequencies that were recorded as a composite of two abundance classes were treated as the more abundant class. An inventory was compiled for all plant taxa recorded on the Capricorn-Bunker Island together with floristic attributes such as family, status and life form. Each plant taxa was given a status of ‘indigenous to coral cays’, ‘native to the mainland’ or ‘exotic’. Plants with unknown origins that are widely distributed in the Indo-Pacific region are assumed to be indigenous to the Capricornia Cays.

Plant voucher specimens were collected during surveys for all species on each island, as well as species that had not been collected in the past ten years. Voucher specimens were incorporated into the Queensland Herbarium (BRI) collection. The Queensland Herbarium records database system (HERBRECS, 2008) was utilised extensively to verify dates and locations of previous botanical collections. Previous botanical reports for the Capricornia Cays were critically examined to identify possible erroneous recordings in the past. Comparison with earlier terrestrial flora lists by Heatwole (1984a; 1984b), Heatwole & Walker (1989), Chaloupka & Domm (1985; 1986), Cribb (1965; 1969; 1972; 1975; 1976; 1979), Cribb & Cribb (1985), Walker (1991a, 1991b), Batianoff (1998; 1999a) and Batianoff & Hacker (2000) were made to assess changes in flora that have occurred over time. Plant species compositions for each island were compared using the Bray-Curtis association analysis function in PATN (Belbin, 2004).

Island disturbance was estimated as a percentage from 0–100% (least disturbed to most disturbed) based on past and present natural disturbances (sea turtle nesting, bird burrows, severe weather, cyclones, scale insect damage, etc.) as well as human activities (resorts, campgrounds, lighthouses, etc.). These rankings are listed in Table 2-1. Details of island features and known disturbance history for each Capricornia Cay were determined from field knowledge and historical data provided by Heatwole (1984a) and QPWS (2000). A higher weighting was given to human disturbances.

3.3 Vegetation

Vegetation mapping of the Capricornia Cays was undertaken by examination of aerial photographs and field sampling. QASCO were commissioned to record new photo imagery for all of the islands within the region as part of this project. The vertical aerial photos used in the aerial photo interpretation are listed in Table 3-2.

Table 3-2. Aerial photographs (2007) and CORVEG sites used in this project.

Island	Run	Frame	Scale	Date	CORVEG sites
North Reef	1	894-895	4000	22/11/2007	6
Tyron Island	1	896-898	4000	22/11/2007	27
North West Island	1	899-902	6000	22/11/2007	18
Wilson Island	1	890-891	4000	22/11/2007	12
Wreck Island	1	888-889	4000	22/11/2007	21
Heron Island	1	886-887	6000	22/11/2007	17
Erskine Island	1	903-904	4000	22/11/2007	16
Masthead Island	1	910-914	4000	22/11/2007	30
One Tree Island	1	882-883	4000	22/11/2007	26
Fairfax Islands	1	871-875	4000	22/11/2007	31
Hoskyn Islands	1	876-881	4000	22/11/2007	-
Lady Musgrave Island	1	864-865	6000	22/11/2007	21
Lady Elliot Island	1	861-863	6000	22/11/2007	13

Vegetation mapping is produced at a map scale between 1:1000 and 1:2000 depending on the size of the island. Digital data are available from the Queensland Government Information Service (2012). The metadata for the digital data is provided in Appendix D. On-ground vegetation sampling involved the use of a series of transects running perpendicular to the shore. Distances were measured along each shore and sampling was either by formal plots or notebook observations. The plot sampling methods described in Neldner *et al*. (2012b) were generally followed. Plot sizes ranged from 1 m^2 for groundcover species, and up to 200 m^2 for the *Pisonia* forests. Percentage cover of each species present and the heights of dominant vegetation were recorded with additional notes on plant condition, soil and other wildlife. The density of trees was determined using plots of variable size ranging from 50–200 m^2. *Pisonia* stem diameters were measured at a height of 30 cm. Where more than one stem at a height of 1.3m from the ground was present, diameters of all stems at 1.3 m were measured. Individuals less than 10 cm in diameter at 30 cm from the ground were not measured. Estimates of height were made using a clinometer and/or visual estimates to the nearest one metre.

The nomenclature given to each vegetation map unit was based on the structural classification of vegetation provided by Neldner (1984). Vegetation community boundaries were determined by aerial photograph interpretation (API), and the vegetation descriptions derived from the 238 plots which are stored in the Queensland Herbarium's CORVEG database. Map unit descriptions provide information of the species frequency and abundance, as well as height and cover information for each structural layer (Neldner *et al*. 2012b).

3.4 Soils

A total of 213 soil samples were collected from the Capricornia Cays during the 2007/08 surveys. Surface soils ('A1 horizons') were sampled at depth of 0–20 cm using a 7 cm diameter sand auger. Deeper profiles ('A2 horizons') were sampled from vegetation communities in roughly 20 cm intervals (i.e. 20-40 cm, 40-60 cm, 100+ cm) until a sharp change in colour was seen and no further organic matter was observable ('C horizons'). Samples were placed into zip-lock bags on site, and dried in the Queensland Herbarium laboratory.

Soils sampled included sediments of beach sands, as well as soil profiles from vegetation of *Casuarina equisetifolia, Argusia argentea, Pisonia grandis* and glades where *Pisonia* had formally been present. Soils were sampled to the maximum depth of 'A' horizons and at the surface of 'C' horizon. This sampling provided information on soil profiles to a maximum depth of 1.1 m.

The chemical component of all soil samples were assessed by the University of Queensland's Analytical Services unit within the School of Land and Food Science. Analyses were conducted for pH, electrical conductivity (dS/m^2), total nitrogen (Wt %), total carbon (Wt %), organic carbon (Wt %), available phosphorus (Colwell-P) (mg/kg), calcium (cmol(+)/kg), potassium (cmol(+)/kg), magnesium (cmol(+)/kg), sodium (cmol(+)/kg), cation exchange capacity (cmol(+)/kg), and total phosphorus (Wt %).

PART B. Results and discussion

4 Flora

The construction of the regional checklist allows comparisons with previous studies (Heatwole, 1984a; Chaloupka & Domm, 1985) and the analysis of species turnover and the identifications of trends in the flora. While the Capricornia Cays native flora is relatively stable, there are changes over time due to the incursions of exotic weeds and the impacts of natural and human disturbances.

4.1 Regional checklist

The checklist of vascular flora of the Capricorn-Bunker Islands (Capricornia Cays) is presented in the Appendix A and has been published in Batianoff *et al*. 2009b. Table 1 provides a summary of the current indigenous and naturalised flora. The combined regional flora of the 15 coral cays contains 131 species, 55 families and 105 genera (

Table 4-1). The Capricornia Cays flora is dominated by dicotyledons (99 spp., 76%), with herbs (89 spp., 68%) the dominant life forms. The most successful families are Poaceae (20 spp., 15%), Asteraceae (10 spp., 8%), Brassicaceae (8 spp., 6%) and Euphorbiaceae (6 spp., 5%). The checklist lists 88 (68%) species of herbs, 21 (16%) species of trees/tall shrubs, 13 (10%) species of shrubs and eight (6%) species of vines.

The indigenous flora of the Capricornia Cays is comprised of 44 species (34%), 31 families and 41 genera. The naturalised flora has 87 species (66%), 38 families and 70 genera including 10 Australian species (8%) that are native to the adjacent mainland, but not indigenous to coral cays (

Table 4-1). Native families with more than one species per family are: Poaceae (5 spp.), Nyctaginaceae (4 spp.), Aizoaceae (2 spp.), Boraginaceae (2 spp.), Convolvulaceae (2 spp.), Euphorbiaceae (2 spp.), Fabaceae (2 spp.) and Moraceae (2 spp.). Prominent naturalised families are: Poaceae (15 spp.), Asteraceae (9 spp.), Brassicaceae (7 spp.), Amaranthaceae (4 spp.), Euphorbiaceae (4 spp.), Agavaceae (3 spp.), Commelinaceae (3 spp.), Malvaceae (3 spp.) and Solanaceae (3 spp.). The indigenous flora is composed of 21 herb species, 14 trees/tall shrub species, five vine species and four shrub species. The naturalised flora life forms are 68 herbs, nine shrubs, seven tree/tall shrub species and three vine species.

4.2 New records

During the 2007/08 surveys, two indigenous species were first recorded for the Capricornia Cays.

(A) *Hernandia nymphaeifolia*, a small tree, was recorded at North West Island as a new record for the Central Queensland region, and the southern limit of its occurrence in Australia. This tropical seashores species occurs throughout northern Australia, New Guinea, Fiji and the Melanesian region. In the Northern Territory it is considered to be vulnerable (Kerrigan & Cowie, 2006).

(B) *Boerhavia* sp. (Bargara L.Pedley 5382), an undescribed perennial herb, was recorded at Lady Elliot Island as a new record for coral cays. This species is widely distributed in tropical northern Australia, Central Queensland and New Guinea.

Twelve exotic species and two mainland native species were discovered as new naturalisations for the Capricornia Cays:

(A) **Amaranthus blitum* (creeping amaranth) was recorded at One Tree Island, the first record for Central Queensland and for coral cays in Australia. This species has a relatively isolated and patchy distribution, limited to the Cape York region of north Queensland, and south-east Queensland.

(B) **Calyptocarpus vialis* (creeping Cinderella weed) was recorded at Heron Island. This weedy plant is widespread along coastal areas of Queensland.

(C) **Cynodon nlemfuensis* var. *nlemfuensis* (Bermuda grass) was recorded at Heron Island. It is widely naturalised in coastal and inland tropical and subtropical areas.

(D) **Sorghum bicolor* (sorghum) was recorded at camping grounds at North West Island. An annual grass that occurs in disturbed areas. It is not considered likely to spread into native forests.

(E) *Agave sisalana* (sisal hemp) was recorded at Lady Elliot Island. It is an escapee from garden areas and is spreading into areas of natural vegetation.

(F) **Mirabilis jalapa* (four o'clock) was recorded at Lady Elliot Island. It was originally planted in the staff residential gardens and has escaped into *Casuarina* forest.

(G) *Tradescantia pallida* (wandering Jew) was recorded at Lady Elliot Island. It was planted in staff gardens and is currently spreading along roadsides in the *Casuarina* forest.

(H) **Tradescantia spathacea* (oyster plant) was recorded at Lady Elliot Island. It was planted in the staff residential gardens and has escaped into *Casuarina* forest.

(I) **Hylocereus undatus* (moonlight cactus) was recorded at Lady Elliot Island. Originally planted in the staff residential gardens, it has now escaped into native forest areas.

(J) # *Dentella repens* (dentella) was recorded at Lady Elliot Island at the rubbish dump. Australian mainland herb that is not expected to spread.

(K) #*Hydrocotyle acutiloba* (pennywort) was recorded at Lady Elliot Island in open grassland area. It occurs in disturbed areas and is not considered likely to spread into native forests.

(L) **Stachytarpheta cayennensis* (snake weed) was recorded at Lady Elliot Island at the rubbish dump. It occurred in disturbed areas and is not considered likely to spread into native forests.

(M) **Chenopodium murale* (green fathen) was recorded at Lady Elliot Island in open grassland area. It occurs in disturbed areas and is not considered likely to spread into native forests

(N) **Gomphrena celosioides* (gomphrena weed) was recorded at Lady Elliot Island in open grassland area. It occurs in disturbed areas and is not considered likely to spread into native forests

Five previously reported species were not found during the 2007/08 surveys. These include **Bromus catharticus, Cocos nucifera, *Conyza canadensis* var. *canadensis*, **Digitaria didactyla* and **Polycarpon tetraphyllum*.

Five species have doubtful origin and status on the Capricornia Cays: *Cocos nucifera, Lepidium englerianum, Plumbago zeylanica, Portulaca oleracea* and *Pseudognaphalium luteoalbum*. In this study, *L. englerianum, P. zeylanica* and *P. oleracea* are assigned an indigenous status. *Pseudognaphalium luteoalbum* is a native species that is non-indigenous on the Capricornia Cays. The origins and the status of *C. nucifera* is unresolved (see Discussion).

Table 4-1. Summary of major plant groups and life forms of the Capricornia Cays

Floristic statistics:	Totals	Dicotyledons	Monocotyledons	Conifers	Ferns
Families	55 31 native 38 exotic	47	7	1	0
Genera	105 41 native 70 exotic	82	22	1	0
Species/entities	131	99	31	1	0
(a) Native to coral cays	44 (34%)	38	6	0	0
(b) Introduced mainland	10 (8%)	6	3	1	0
(c) Exotic	77 (59%)	55	22	0	0
Total naturalised	87 (66%)	61	25	1	0
Life forms:					
Native species					
Trees / tall shrubs (>2m)	14 (11%)	13	1	0	0
Shrubs	4 (3%)	4	0	0	0
Herbs – annual	7 (5%)	7	0	0	0
Herbs – perennial	14 (11%)	9	5	0	0
Vines	5 (4%)	5	0	0	0
Naturalised species					
Trees / tall shrubs (>2m)	7 (5%)	6	0	1	0
Shrubs	9 (7%)	4	5	0	0
Herbs – annual	47 (36%)	37	10	0	0
Herbs – perennial	21 (16%)	11	10	0	0
Vines	3 (2%)	3	0	0	0

4.3 Patterns of species distribution

4.3.1 Geographic limits

Eleven species (25%) of the entire coral cay native flora reach their southern limit of their Australian distribution at the Capricornia Cays (Table 4-2). A few plants of *Suriana maritima* have been found on the mainland at one location (Rodds Peninsular National Park) which is now the most southern location for this species. However, the rest of the population of *S. maritima* is found at the Capricornia Cays. Two taxa are known only from the study area in Australia (*Boerhavia albiflora* var. *heronensis* and *Trachymene cussonii*).

Table 4-2. Plant species with northern and southern geographic limits at the Capricornia Cays

Northern and Southern Limits
Abutilon albescens – Malvaceae: Shrub Torres Strait to Lady Elliot Island (24º07’S, 152º 43’E) + Northern Territory, New Guinea, New Caledonia
Boerhavia albiflora var. ***heronensis*** – Nyctaginaceae: Herb This variety is endemic to the Capricorn-Bunker Islands. Southern limit: Lady Elliot Island (24º07’S, 152º43’E), northern limit: North West Island (23º12’S, 151º42’E)
Chamaesyce atoto – Euphorbiaceae: Annual herb Cook district to West Hoskyn Island (23º48’S, 152º17’E) + Northern Territory, New Guinea, New Caledonia
Commicarpus insularum – Nyctaginaceae: Vine Mainly Port Curtis, one record in North Kennedy district (19º58’S, 145º35’E). South to Hoskyn Island (23º48’S, 152º17’E)
Cordia subcordata – Boraginaceae: Tree Cook district to Masthead Island (23º32’S, 151º43’E) + New Guinea, Northern Territory, New Caledonia
Hernandia nymphaeifolia – Hernandiaceae: Tree Cook and North Kennedy districts. Previously, only as far south as Zoe Bay, Hinchinbrook Island (18º23’S, 146º19’E) + New Guinea, New Caledonia.
Lepidium englerianum – Brassicaceae: Annual herb Cook district to Fairfax Island (23º51’S, 152º22’E – Collected in 1927) + New Caledonia
Pisonia grandis – Nyctaginaceae: Tree Cook district to Lady Elliot Island (24º07’S, 152º43’E) + New Caledonia
Stenotaphrum micranthum – Poaceae: Herb Cook District to West Hoskyn Island (23º48’S, 152º17’E) + New Guinea
Triumfetta procumbens – Sparrmanniaceae: Herb Cook district to Lady Elliot Island (24º07’S, 152º43’E) + New Guinea, New Caledonia
Trachymene cussonii – Apiaceae: Annual herb Has been reviewed by Holland (1989). Native to Vanuatu, New Caledonia and Australia, it is restricted to the Capricorn-Bunker Islands in Australia. Southern limit: Lady Elliot Island (24º07’S, 152º43’E). Northern limit: Tryon Island (23º15’S, 151º47’E) + Vanuatu and New Caledonia

Notes: New Caledonia information from Morat et al. (2001)

4.3.2 Rare species

Frequency of occurrence of species on each island is given in Appendix A. Rare species occurrences, i.e. one to three individual indigenous plants currently found in only one location are *Calophyllum inophyllum* (North West Island), *Clerodendrum inerme* (Masthead Island) and *Hernandia nymphaeifolia* (North West Island). Rare species represented by a few individuals and found on one or two cays include *Stephania japonica* (Masthead Island), *Triumfetta procumbens* (Fairfax West Island and Lady Elliot Island) and *Ximenia americana* (Tryon Island). Other species with limited distributions include *Boerhavia* sp. (Bargara L.Pedley 5382) at Lady Elliot Island) and an annual herb *Salsola kali* at Erskine and Masthead Islands.

Fifty-five exotic species are found on only one island within the Capricornia Cays (Appendix A). Of these, 47 species are limited to Lady Elliot Island, however not all are considered rare on Lady Elliot Island. For example, **Lantana camara* was recorded as abundant and **Stenotaphrum* *secundatum*, **Eragrostis tenuifolia*, **Bryophyllum delagoense*, **B. pinnatum* and **Alternanthera pungens* were relatively frequent at Lady Elliot Island (Appendix A).

4.3.3 Abundant species

The two most abundant exotic species in the study areas are **Cakile edentula* (13 islands) and **Solanum americanum* (12 islands). The ten most widely distributed indigenous plant species on the Capricornia Cays are listed in Table 4-3. Four indigenous species are found on all fifteen islands: *Casuarina equisetifolia* subsp. *incana*, *Pisonia grandis*, *Argusia argentea* and *Achyranthes aspera*. The first three species are dominant in vegetation communities that make up 78% of the island vegetation. While 80% of indigenous species are either rare or infrequent, 98% of the exotic species are rare or infrequent, many of them only occurring on Lady Elliot Island (Figure 4-1).

Table 4-3. List of the ten most frequent/abundant species at Capricornia Cays

Plant Taxa	No. islands
Achyranthes aspera	15
Argusia argentea	15
Casuarina equisetifolia subsp. *incana*	15
Pisonia grandis	15
Abutilon albescens	14
Boerhavia albiflora var. *heronensis*	14
Lepturus repens	14
Thuarea involuta	13
Ficus opposita	12
Pandanus tectorius	12

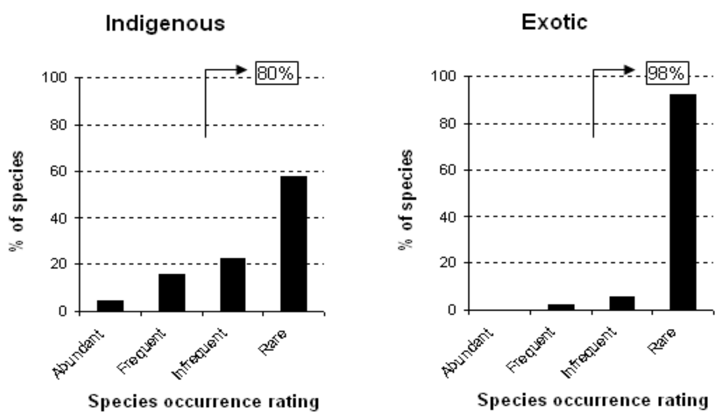


Figure 4-1. Proportion of species making up each abundance category for native (n=44) and exotic (n=87) floras.

Total species richness (occurrences) ranged from 16 species at North Reef Island to 97 species at Lady Elliot Island (Appendix A). Fairfax (East) Island had the lowest indigenous species richness (12 spp.) and Masthead Island had the highest (35 spp.). The number of exotic species recorded from each island varied from one species at Erskine to 76 species at Lady Elliot Island. The relationship between island area size and the number of native and naturalised species is given in Figure 5-2. A very weak trend was observed for indigenous species richness and island areas. However, there was no relationship between the number of exotic species and the size of island areas (Figure 4-2).

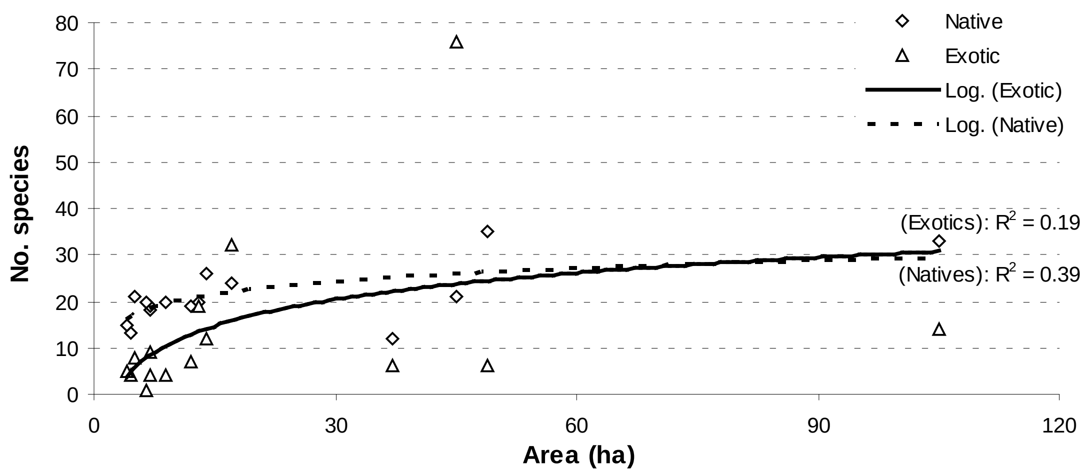


Figure 4-2. Species richness curve for native (n=44, R^2 = 0.39) and exotic species (n=87, R^2=0.19) at the Capricornia Cays.

4.4 Character of flora

The regional importance of the Capricornia Cays flora is highlighted by the presence of the endemic taxon *Boerhavia albiflora* var. *heronensis* and *Trachymene cussonii*. It is significant that it forms the southern limit refuge for many GBR coral cay species in Australia and the tropical world (Table 4-2). This includes some of the most characteristic species of low island floras that are widely distributed in the Indo-Pacific Oceanic region, such as *Argusia argentea*, *Cordia subcordata*, *Lepidium englerianum* and *Pisonia grandis*. According to Batianoff *et al*. (2008b, 2009a), the flora of Coral Sea cays including the Capricorn-Bunker Islands are a subset of tropical flora found in the Indo-Pacific region. The connectivity of flora between distant islands is due to the South Equatorial Current, which reaches the Great Barrier Reef to the north of the study area, and the East Australian Current that operates southwards along the mainland coast (Wachenfeld *et al*., 2007). Together with the seabirds inhabiting the Capricornia Cays, these currents disperse coral cay plant propagules across very long distances (Batianoff *et al*., 2008b, 2009a). As a result, the flora of the Capricornia Cays has an affinity with islands elsewhere in the western Pacific Ocean as well as with the mainland of Australia (Batianoff & McDonald, 1980; Walker, 1991a; QPWS, 2000).

According to Stoddart and Fosberg (1991), the southern and northern Australian coral cays floras are different from the neighbouring islands of Melanesia. For example, neither of the two GBR cay provinces have orchids or ferns as common species. At the same time, the southern and northern coral cays are different from each other. The flora of the southern GBR cays are said to be characteristically ‘Indo-Pacific’ (Stoddart & Fosberg, 1991). The *Pisonia* forests at the Capricorn-Bunker Islands define the character of this region, whereas *P. grandis* occurs infrequently on the northern cays (Walker, 1991a). The southern cays also differ from the northern cays in not having mangroves, having fewer rock platform succulents and a much lower number of littoral rainforest species. The native flora of the northern cays is considered to be more similar to the Australian mainland and with species richness several times greater than the flora of southern cays (Walker, 1991a; Stoddart & Fosberg, 1991).

The wetter climate in the northern region and the closer proximity to the mainland provides for higher plant diversity. Avifauna and humans are other ecological factors likely to have contributed to the distinctiveness of the regions. The major disperser of fleshy rainforest species, the pied imperial pigeon (*Ducula bicolor* (Gray)), is seasonally abundant on most of the northern cays but it is absent at the southern cays (Crome, 1975). Selective planting of useful medicinal and food plants by humans on the northern islands may have occurred and increased their species diversity (Stoddart & Fosberg, 1991).

4.5 Species richness

The indigenous species richness at Capricorn-Bunker Islands is higher than the Caroline Atoll Group islands (10º00'S, 150º14'W, Republic of Kiribati, central Pacific Ocean) where the average indigenous species richness of islands ranging in size from 4-70 ha rarely exceeded 18 species (Kepler & Kepler 1994). The number of indigenous species in the Capricornia Cays is also much higher than the cays contained within the remote Coringa-Herald National Nature Reserve in the northern Coral Sea Islands Territory (Batianoff *et al*., 2008b, 2009a).

The theory of island biogeography proposes that the number of species present on any island is determined by its size and degree of remoteness (MacArthur & Wilson, 1967; Whittaker & Fernández-Palacios, 2007). However, in this study the relationship between island area and the number of native and naturalised species is very weak (Figure 4-2). It is apparent that species richness of low cays is more influenced by other factors than the size of the cays. Total species richness ranged from 16 species at North Reef Island to 97 species at Lady Elliot Island (Appendix A). Fairfax (East) Island had the lowest indigenous species richness (12 species) and Masthead Island had the highest (36 species).

4.6 Species of doubtful status

The status of coconut *Cocos nucifera* is contentious. According to the senior author's field observations, the species does naturalise along the Queensland coast, but it is not invasive. Native-wild and/or cultivated coconuts were recorded at North Reef, Tryon, One Tree, North West, Wilson, Wreck, Heron, Hoskyn (West) and Lady Elliot Islands (Heatwole, 1984a). Coconuts are not reported for any of the Capricornia Cays in the checklist of Chaloupka and Domm (1985). In the late 1980s and to the present, all populations of coconuts found on cays administered by QPWS have been removed. As a result, this species is no longer found growing in the Capricornia Cays as remnant wild populations and/or as a naturalised species. During the current surveys, cultivated *C. nucifera* populations were only found on cays administered by the Commonwealth (North Reef and Lady Elliot Islands).

Early botanists and biogeographers frequently commented that coconuts in Australia were not common, but at the same time many explorers believed that coconuts were indigenous to Australia (Macgillivray, 1852; Bentham, 1878). According to Bostock & Holland (2010), *C. nucifera* is an introduced exotic to Queensland. In Volume 50 of the Flora of Australia, Du Puy and Telford (1993) state that coconuts are native to the Indo-Pacific Region including Australia. However, much of the current coconut drift seed that arrive at the Capricornia Cays probably originate from cultivated and/or naturalised populations. These coconuts are therefore not indigenous to Capricornia Cays and have not been included in the regional checklist of flora (Appendix A).

Lepidium englerianum and *Portulaca oleracea* are listed as naturalised exotics in Queensland (Bostock & Holland, 2010). According to Batianoff (2001), *Lepidium englerianum* is an endemic species to coral cays. Field observations along the Great Barrier Reef indicate that *L. englerianum* and *P. oleracea* are widely distributed and are part of the natural coral cay flora (Batianoff *et al*., 2008b, 2009b).

Plumbago zeylanica is recognised as native to Australia (Bostock & Holland, 2010; Du Puy & Telford, 1993d). According to Ridley (1930), *P. zeylanica* has an African/Asian origin and was introduced into Australia during the early 1800s in contaminated imports. It is currently widespread across subtropical Africa, southern Asia, northern Australia and some Pacific Islands (Du Puy & Telford, 1993d).

Pseudognaphalium luteoalbum is considered native to the mainland of Australia (Bostock & Holland, 2010). However, the status of this species is doubtful due to its complex taxonomy. Field observations show that its distribution and growth are indicative of a weedy plant species. As a result, it is considered exotic to the Capricornia Cays.

4.7 Comparison of island floras

4.7.1 Similarity index

The fusion dendrogram of indigenous species (Figure 5-3) shows that the Capricornia Cays can be more or less separated into two groups. The first group includes North Reef, One Tree, the Hoskyn Islands, the Fairfax Islands, Lady Musgrave and Lady Elliot. The second group includes Tryon, North West, Wilson, Wreck, Heron, Erskine and Masthead Islands. The floristic associations between Capricornia Cays are shown to be relatively similar using native only (Figure 5-3) and combined native and naturalised (Figure 5-4) floristic data. The distinctiveness of Lady Elliot Island's flora is due to the high number of species that have naturalised only at Lady Elliot Island (47 species), and it forms a separate outlier in the combined flora dendrogram.

The separation of islands into two distinct groups based on native flora species richness could be due to the closeness of islands to each other and/or the 'distal' and 'proximal' location relative to mainland. The southern Capricornia Cays are closer to the edge of the continental shelf and could therefore by subject to higher exposure to wind and waves. The northern group are closer to the mainland and more protected. The inclusion of North Reef Island in the southern group could be due to the low number of indigenous species recorded on the island (13 species), and the comparatively low abundance of key species such as *Pisonia grandis*.

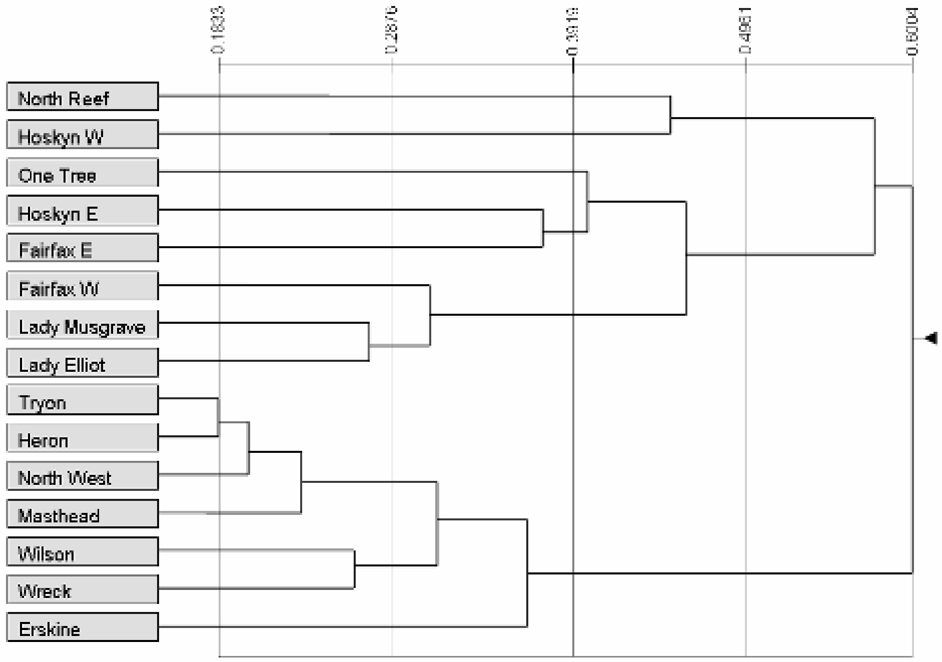


Figure 4-3. Fusion dendrogram of the floristic association of native species on the Capricornia Cays based on Belbin's (2004) PATN analysis using plant presence/absence data.

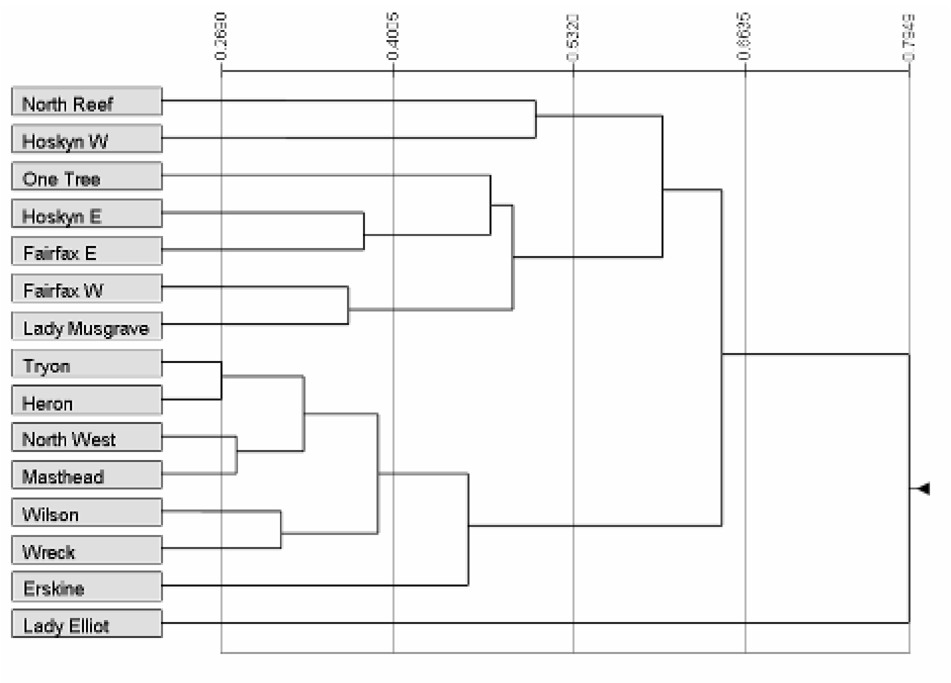


Figure 4-4. Fusion dendrogram of the floristic association of all species on the Capricorn-Bunker Islands based on Belbin's (2004) PATN analysis using plant presence/absence data.

4.7.2 Disturbance

All cays are subject to some natural disturbances by wildlife and weather conditions. The level of human disturbance ranges from very low to very high. Table 2-1 provides some of the known information of historic and current disturbances, as well as a percentage of overall disturbances for each island. The percentage of exotic species in each island's floras increased with higher levels of disturbance (Figure 4-5). Erskine, Wreck and the Hoskyn Islands with the lowest estimated disturbance level (around 20%), had the lowest percentage of exotic species (14.9%). The islands that were estimated at about 30% disturbed (North Reef, Tryon, Masthead, One Tree and the Fairfax Islands) had an average of 24.8% exotic species. North West, Wilson, Heron and Lady Musgrave Islands were estimated to be around 60% disturbed and had an average of 31.2% exotic species. The naturalised non-indigenous species made up 78% of the flora of Lady Elliot Island, which is the most disturbed of all islands surveyed (90% disturbed) (Figure 4-5).

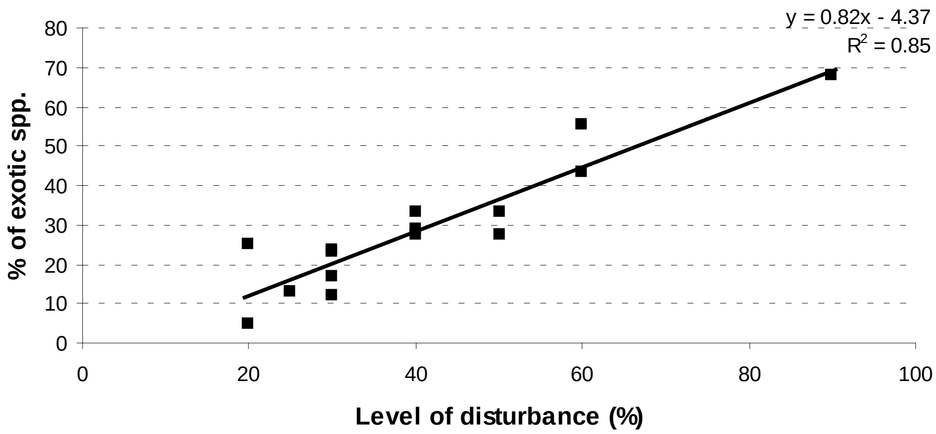


Figure 4-5. Relationship between estimated disturbance levels at each island and the percentage of exotic species in its floristic composition.

The exotic African big-headed ant *Pheidole megacephala* has been found on 11 of the 14 islands surveyed by Burwell *et al*. (2010, 2012). The inter-island distribution was strongly correlated with the amount of human visitation and the degree of disturbance on the islands.

4.8 Temporal patterns & human impacts

In terms of species the Capricornia Cays flora is dominated by short-lived herbs (54 species, 41%) indicates an adaptation of the regional flora to the dynamic local environment. The high percentage of rare and infrequent species (80% indigenous, 98% exotic) within the current Capricornia Cays flora compared to the Sunshine Coast on the mainland (62%) indicates that very few species have the potential for dominance (Batianoff & Burgess, 1993). Heatwole (1976; 1984a) and Batianoff (1999b) stated that coral cay floras generally have very high species turnover. Many species may establish for limited duration, surviving for some time in very low numbers. The dominance of dense to mid-dense canopies of communities of *Pisonia grandis, Argusia argentea, Casuarina equisetifolia* or *Scaevola taccada* with little or no herb species limit the potential establishment and spread of new plant species arrivals. The higher incidence of rarity in the exotic species compared to the indigenous species is most likely due to their recent establishment. In addition, the majority of exotic species are short-lived herbs (54%) indicating a preference for disturbance caused by human activities (Table 1).

It is difficult to comment on long term changes to the regional flora of Capricornia Cays, as most of the past regional studies used lists derived by compilation of anecdotal records gathered over long periods of time. The list of Heatwole (1984a) of 85 species with 41 exotics (48%) and Chaloupka and Domm (1985) of 85 species including 46 exotics (54%) were updated to the current nomenclature and erroneous records removed. The current checklist includes 121 total species (excluding naturalised mainland Australian species). The current data indicate that numbers of exotic species have risen to 77 (59%), which is a rate of increase of 1.5 species per annum. *Bromus catharticus, Conyza canadensis* var. *canadensis*, *Digitaria didactyla* and *Polycarpon tetraphyllum* were not recorded in the 2007/08 surveys.

The number of native species in this region over the last 24 years remains relatively static. Heatwole (1984a) lists 44 native species, Chaloupka and Domm (1985) recorded 39 species and the current checklist (Appendix A) lists 44 species. However, other changes have occurred on individual islands. For example, some of the more common species of the mid 1980s surveys are no longer widespread.

Spinifex sericeus, a perennial grass, was no longer recorded at North Reef, Tryon, Heron, One Tree, Hoskyn East, Hoskyn West, Lady Musgrave and Lady Elliot Islands. *Trachymene cussonii*, an annual herb, was common and abundant on most islands in 2007/ 2008 but was previously recorded as infrequent and/or rare at Masthead, One Tree, Fairfax West and Lady Elliot Islands. *Ipomoea pes-caprae* subsp. *brasiliensis*, a perennial herb, was not recorded at North Reef, Tryon, North West, Wreck and Fairfax East Islands. *Chamaesyce atoto* an annual herb was not recorded at Wilson, Heron, One Tree, Hoskyn East, Fairfax East and Fairfax West and Lady Elliot Islands. *Tetragonia tetragonioides* an annual herb was not recorded at North Reef, Heron, Hoskyn West and Fairfax West Islands. It is important to note that most of the above native species that were once present on an island, but not found during the current surveys, are the littoral species. The population losses of these beach plants may simply indicate loss and/or erosion of sandy beaches at the Capricornia Cays.

Olds *et al*. (in prep.) discusses the recent predominance of drought in relation to scale insect outbreaks on *Pisonia grandis*. The *P. grandis* forest on Tryon Island was almost completely destroyed (88%) by an outbreak of the soft scale *Pulvinaria urbicola* (Cockerell) (Olds *et al*. 1996; Olds *et al*. in prep.). The loss of this almost monospecific stand at Tryon Island has allowed the expansion of other species including weeds.

Chaloupka & Domm (1986) stated that human visitor numbers are highly correlated to the number of exotic species. However, Heatwole & Walker (1989) suggested that the nature of human activities rather than numbers alone was more critical. The high number of exotic species present on Lady Elliot Island was mainly a consequence of human activities (Batianoff, 1998). In this study the intensity of human disturbance is clearly shown to be the major factor contributing to the establishment and spread of exotic species (Table 4). The islands with a disturbance level less than 50% recorded an average of 21% exotic species. Islands with a disturbance level of more than 50% recorded an average of 46% exotic species. The exotic species at Lady Elliot Island (around 90% disturbed) make up 68% of its flora (Figure 6). Forty-seven species (36.1%) of weeds found on Lady Elliot Island are not present on any other Capricornia Cay. If Lady Elliot Island was excluded, the exotic species for the region would be reduced to 39 species, i.e. 30% of the total flora.

5 Vegetation

5.1 Vegetation communities

The vegetated and unvegetated areas of the Capricornia Cays are classified as separate entities.

The disturbed and naturally unvegetated areas include three map units: sandy shores, lithified shores, and high human impact areas. Common types of human disturbance included the resorts and research stations infrastructure, camping grounds and lighthouses.

The vegetation includes 29 vegetation communities that are found either at the shore, on the beach ridges, and in the interior of islands. These communities have been mapped at 1:1000 - 1:2000 scale. The communities that are dominated by native species have been assigned to new regional ecosystems (12.2.18, 12.2.19, 12.2.20, 12.2.21) and a new subregion for Southeast Queensland {Southern Great Barrier Reef Subregion (12.12)} has been erected to accommodate the unique vegetation of the Capricornia Cays.

Vegetation Communities		**Regional Ecosystems**
Disturbed & Naturally Unvegetated Areas		
A	Sandy shores	
B	Lithified shores	
C	Disturbed areas (high human impact)	
D	Shingle shores with sparse vegetation e.g. *Canavalia rosea*	**12.2.14h**
E	Steep eroded coral shores, e.g. Wilson Island	
Foreshore Beach Vegetation		
1a	**Cakile edentula* ephemeral herbland	**12.2.14f**
1b	*Spinifex sericeus* open-hummock grassland	**12.2.14e**
1c	*Sporobolus virginicus* tussock grassland	**12.2.14d**
1d	Seashore mixed herbland	**12.2.14i**
1e	Very sparse herbland, mainly sand (North Reef)	**12.2.14g**

Note: It was only possible to separate these foreshore herblands where sites were visited. These communities can change composition and distribution after major coastal events e.g. cyclones.

Frontal Beach Ridge Vegetation

2a *Argusia argentea-Scaevola taccada* open-scrub (littoral scrub)+/- *Pandanus tectorius* emergents (Masthead) **12.2.19a**

2b *Argusia argentea* open-scrub with *Casuarina equisetifolia* subsp. *incana* emergents **12.2.19b**

Interior Ridges, Swales, Plains Vegetation

3a *Naturalised herblands to shrublands (on Tryon can be dominated by **Solanum americanum* or **Euphorbia cyathophora*, or **Eleusine indica* or **Cenchrus echinatus* or *Commicarpus insularum*; on Lady Elliot by **Euphorbia cyathophora* and *Canavalia rosea*)

3d **Lantana camara* closed-scrub (Lady Elliot)

3e Mown airstrip of **Cynodon dactylon*, **Eragrostis tenuifolia* (Lady Elliot)

3b Ephemeral wetlands **12.2.17c**

3c *Sesuvium portulacastrum* herbland **12.2.17b**

4 Mixed tussock grassland/herbland **12.2.17a**

5a *Wollastonia biflora* +/- *Abutilon albescens* +/- *Plumbago zeylanica* herbland **12.2.18a**

5b *Plumbago zeylanica / Canavalia rosea / Lepturus repens* herbland **12.2.18b**

5c *Abutilon albescens* shrubland. Can include *Caesalpinia bonduc* (LM) **12.2.18c**

6 *Suriana maritima* open- to closed-scrub **12.2.19c**

7 *Scaevola taccada* open- to closed-scrub **12.2.19d**

8a *Casuarina equisetifolia* subsp. *incana* woodland to low open-forest **12.2.14a**

8b *Casuarina equisetifolia* subsp. *incana* woodland to low open-forest with mid dense shrub of *Argusia argentea/ Scaevola taccada* (Masthead) **12.2.14b**

8c *Casuarina equisetifolia* subsp. *incana* open-forest to woodland with *Pandanus tectorius* subcanopy (Wilson) **12.2.14c**

9 *Pandanus tectorius* low open-forest to low closed-forest **12.2.20a**

10 *Celtis paniculata* +/- *Pisonia grandis* +/- *Pandanus tectorius* woodland to closed-forest **12.2.20b**

11a *Pisonia grandis* low open-forest to low closed-forest **12.2.21a**

11b *Pisonia grandis* closed-forest to low closed-forest, sometimes with *Pandanus tectorius* (Wilson, LM, NW), *Celtis paniculata* (NW) and *Ficus* spp. (LM) **12.2.21b**

12a *Ficus rubiginosa* open-forest **12.2.21c**

12b *Ficus opposita* shrubland (Fairfax) **12.2.21d**

13 *Casuarina equisetifolia* subsp. *incana* planted woodland with mixture of naturalised and native species in the understory (Lady Elliot). **Non-remnant**

Populations not extensive enough to map

\# *Ximenia americana* closed-scrub

@ *Cordia subcordata* low closed-forest

Technical descriptions of the plant communities recorded on each of the Capricornia Cays have been produced by Neldner *et al*. (2012a). These descriptions are based on the 238 sites sampled on the islands. The pre-clearing distribution of communities on islands mined for guano from 1891 to 1900 are speculative, and based on historic accounts, old photographs and the remnant vegetation currently present.

The technical descriptions and A3 maps of the vegetation communities of each island overlying aerial photography at a scale of 1:1000-1:5000, are available online (Neldner *et al.* 2012a). The digital data in shapefile format are available from QGIS at http://dds.information.qld.gov.au/dds/.

5.2 Vegetation condition

Vegetation condition varies due to prevailing seasonal trends, forest age/health and pest damage. During our surveys most of the vegetation communities at Capricornia Cays were healthy and showing normal growth patterns. The uneven *Pisonia* forest canopies visible on aerial photographs can be explained by the presence of natural canopy gaps. Some large gaps were glades formed by fallen senescent trees. During winter 2007, the Central Queensland coast experienced dry conditions and cooler temperatures than the long-term seasonal averages. As a result, some 30–50% of *Pisonia* foliage was showing yellowing of leaves and there was some leaf fall.

Some of the island's frontal seashore forests were also undergoing changes due to erosion by high seas (e.g. Masthead Island). The species composition of seashore herblands is dynamic because of erosion and subsequent establishment of invasive species such as the *Cakile edentula*. Common seashore species recorded some 10 or 20 years ago, such as *Spinifex sericeus* and *Ipomoea pes-caprae*, are no longer common. Recruitment of *Casuarina* seedlings along the shores was relatively uncommon under the climatic conditions experienced at the time (Figure 6-3).

5.2.1 Condition of *Pisonia grandis*

Pisonia grandis stands at Wilson Island were affected by pest scale insect (*Pulvinaria urbicola*) outbreaks during 2006/07. A biological control program using the predatory ladybeetle *Cryptolaemus montrouzieri* was effective in controlling the scale insect and thereby preventing the loss of *Pisonia grandis* (Olds, 2006). During the 2007/2008 fieldwork, other cays were examined for evidence of scale insect (*Pulvinaria urbicola*) and hawkmoth larvae (*Hippotion velox*) defoliation. There was no sign of these two insect pests in the areas surveyed. Severe defoliation by hawkmoth caterpillar did however occur on Wilson Island in January 2008 and Masthead Island in June 2010 (Alan Hollis, pers. comm.). On Tryon Island, the high infestations of *Pulvinaria urbicola* scale of the early 1990s have disappeared and some remnant *Pisonia* patches were showing recovery post scale insect damage (Figure 5.1).

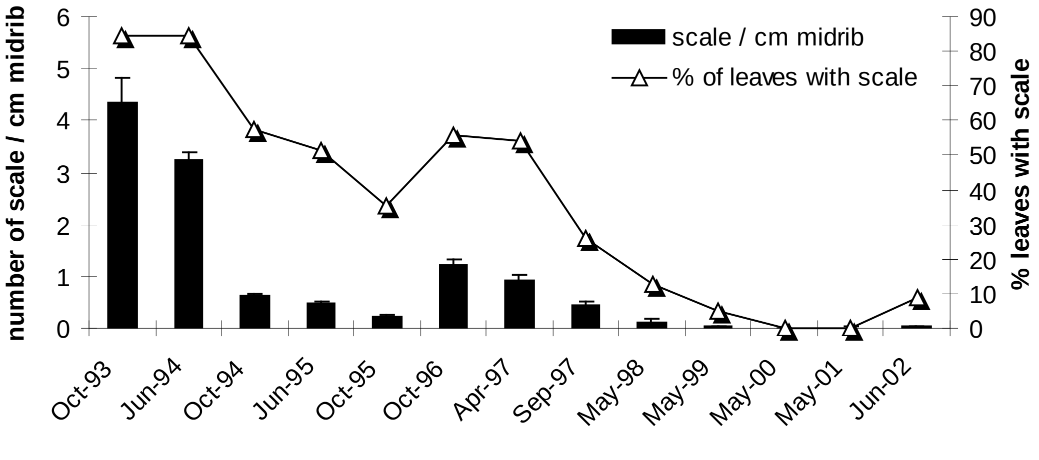


Figure 5-1. Recorded levels of *Pulvinaria urbicola* scale on *Pisonia grandis* leaves at Tryon Island (Sourced from Kay *et al*., 2003).

Large and small canopy gaps, resulting from tree falls, were common throughout the *Pisonia* forests, particularly in the old-growth and mature forests areas at North West and Masthead Islands. In some cases large old trees had fallen because they had become so top-heavy that they were not able to be supported by the existing root system. Some fallen trees were broken at the base, whereas others remained intact but uprooted – revealing the shallow root structure of up to one metre deep.

Most fallen *Pisonia* trees (16–20 m tall) re-sprout vegetatively from the main trunk and/or by the main branches layering, hence there is frequently a large number of small diameter stems present in these stands (Figure 5-2). The episodic build-up of forest structure and break-down phases in *Pisonia* forests are referred to as a "fluctuating climax" (Specht & Specht 1999, Batianoff & Naylor 2007)). The success of vegetative reproduction in the *Pisonia* forest is likely to lead to a narrow genetic pool, particularly on the older cays such as on North West Island.

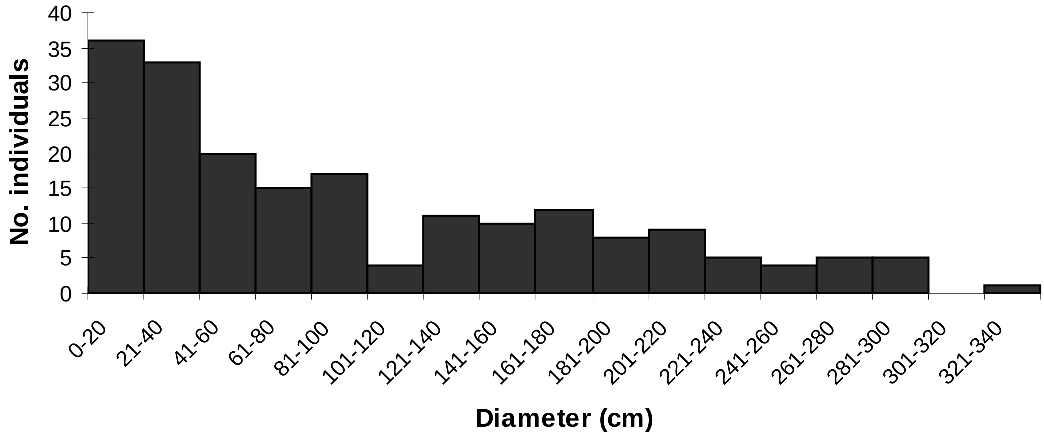


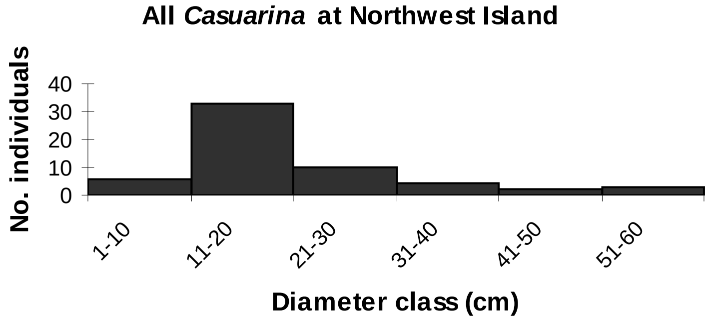
Figure 5-2. Diameter classes (20cm) of old-growth *Pisonia grandis* at North West Island: 2007 (n=195)

Gap formation allows sunlight to reach the ground and shrubs and herbs to establish and form 'glades' within the *Pisonia* forest. The glades are most frequently colonised by native species such as *Abutilon albescens* (shrub) and *Wollastonia biflora* (sprawling herb). Other native species occurring in the glades include *Achyranthes aspera, Thuarea involuta, Ficus opposita* and *Pipturus argenteus*. Weeds such as *Eleusine indica, Solanum americanum, Amaranthus viridis* and *Passiflora suberosa* also take advantage of the glades. The size of the glades within the forest vary from approximately 220-1200m^2. New growth of small *Pisonia* trees slowly encroaches on the glades and replaces the *Abutilon-Wollastonia* shrubland.

At North West Island and other islands, the *Pisonia* forest on the edges of each community appear to be expanding vegetatively (stem layering) into undeveloped seashore soils currently occupied by *Argusia-Scaevola* open-scrub and/or *Casuarina* woodland. This spread is facilitated by the 'new' *Pisonia* plants staying attached to the parent plants for relatively long periods, during which time the soil fertility levels improve. *Pisonia* forests appear to exhibit faster growth along the SE shorelines compared to other shorelines because of the more open habitat and reduced competition from other trees.

5.2.2 Condition of *Casuarina equisetifolia*

Interpretation of the diameter and height dimensions of *Casuarina equisetifolia* trees may aid in the interpretation of accretion and erosion patterns of the islands. *Casuarina* stands most often establish during seashore accreting periods and grow as part of the strand vegetation. The diameter classes at North West and Wreck Islands indicate poor recruitment in recent times. The size and condition of *Casuarina* woodlands will deteriorate if older trees die without being replaced (Figure 5-3).



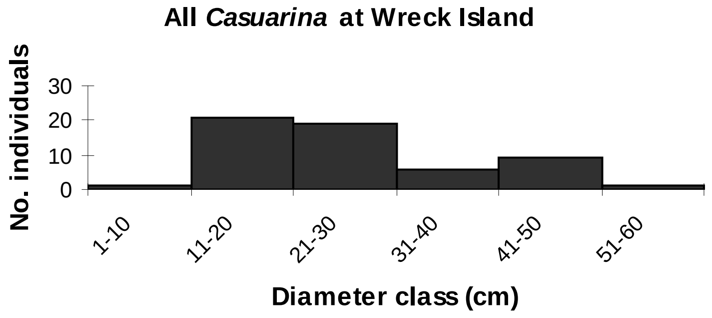


Figure 5-3. Diameter classes at 30 cm height of *Casuarina equisetifolia* at North West Island and Wreck Island.

6 Soils properties

6.1 Overview

The complexity of island types and the current and historic land use in the Capricornia section of the Great Barrier Reef create a variety of soil conditions. Land uses affecting soils in the Capricornia section include guano and phosphate rock mining (Daly & Griggs, 2006) and resort construction. The removal of 1m of topsoil from Lady Elliot Island extensively altered the soils on this island. Islands that have seen extensive human-induced changes to soil conditions include the islands that have been mined for guano and phosphate rock (Lady Elliot Island, Tryon Island, North West Island) and those with resorts and research stations (Heron Island, Lady Elliot Island, Wilson Island and One Tree Island).

Soils of the Capricornia Cays range from the unweathered beach sands to the fertile A horizon sandy soils. Larger cays, such North West Island and Masthead Island, that have an interior of old-growth *Pisonia grandis* have pockets of peaty humus up to 25 cm deep with pH levels as low as 4.5 (Batianoff 1999a). A “mor” or raw humus layer within *Pisonia grandis* communities has been described by Fosberg (1954).

6.2 Soil classification

The parent material of the low coral cays across the Pacific is essentially homologous, being derived from detritus of marine organisms such as coral, calcareous algae and other invertebrates. Coral cay substrates are calcareous due to their high calcium carbonate mineralogy, with a high proportion of medium sand textures. The undeveloped soils are alkaline. As the soils develop and accumulate organic matter the pH changes from alkaline to neutral to acidic. Coral cay soils usually have little to no profile development beyond some accumulation of organic matter in the A-horizon. The absence of a B-horizon indicates recent development and/or a lack of weathering from the original marine deposits.

Due to the unique character of reef substrates, the calcareous soils of Pacific low atolls have most often been referred to as a 'Jemo' series frequently containing formations of phosphate rock (Fosberg, 1954). Coral island soils have also been called 'Entisols' (Morrison 1990) and 'Calcarenite Proposols' (Hearty and Vacher 1994). Both terms refer to their recent development. Woodroffe and Morrison (2001) have described them as weakly developed Regosols or Lithosols within the Typic Topopsamments. According to Morrison (1990), current soil taxonomy systems do not adequately describe the soils of coral cays.

The chemical and physical characteristics of the Capricornia Cays soils best align with the shelly calcarosols of the CSIRO compendium of Australian soils (McKenzie *et al*., 2004). According to Batianoff *et al*. (2008b) the Australian coral cay group of soils are 'inceptic coral calcarosols'. This name refers to soils that are recent, organic, dominated by calcium carbonate derived from coral reef ecosystems and within the order of calcarosols. Essentially, inceptic coral calcarosols are neutral to strongly alkaline, lacking a 'B' horizon, with loose surface soils, no consolidation of particles and the parent material derived from marine organisms.

6.2.1 Seashore soils

Soils sampled from the sandy beaches, ephemeral herblands, *Sporobolus virginicus* and *Spinifex sericeus* grasslands, and seashore *Argusia argentea* and *Casuarina equisetifolia* stands were all classified as seashore soils. These soils are almost wholly biogenically-derived. That is, the sediments consist of marine-derived organic compounds from skeletons, corals, calcareous algae, molluscs, forams and bird excreta. Seashore soils are unstructured white to grey in colour, calcareous and have a grain size ranging from very fine to coarse – the latter being most common. Some larger coral fragments are present. They have a low nutrient content compared to beach ridge and interior soils. Their chemical properties are presented in Table 6-1**Error! Reference source not found.** and Figures 6-1 to 6-5. They have a depth of 0-20cm.

6.2.2 Beach ridge soils

The beach ridge communities consisted of *Argusia argentea, Suriana maritima* and *Casuarina equisetifolia*. The beach ridge soils are freely drained with an unconsolidated surface covered with some plant litter. The physical properties of the interior beach ridge soils were very similar to the seashore soils. The beach ridge surface soils were darker in colour (grey to pale brown) with deeper 'A' horizons (40–60 cm) than the seashore soils. Nutrient levels are higher in the beach ridge soils than the seashore soils (Table 6-1 and Figure 6-1 to 6-5).

6.2.3 Interior plains soils

The interior plains communities of the Capricornia Cays included the herblands, woodlands, scrubs and *Pisonia* stands. The interior soils are freely drained with an unconsolidated surface covered with moderate to high plant litter material. The physical properties are similar to the beach ridge soils. The interior soils are however, more weathered with finer sand grains and higher organic matter, and therefore darker in colour (pale brown to dark grey). The interior soils had the deepest 'A' horizons (60-110 cm) of all the cay soils. Nutrients levels are high compared to the other seashore soils (Table 6-1 and Figure 6-1 to 6-5).

6.3 Chemical properties

A comparison of chemical properties of soils, at various depths, for the major landforms is presented in Table 6-1. Comparisons of soil pH (pH), organic carbon (OC), total nitrogen (TN), phosphorous (Colwell-P), calcium (Ca) and potassium (K) are presented for each landform and its vegetation community in Figures 6-1 to 6-5, respectively. In general the soil chemical properties of Capricornia Cays were similar to the patterns recorded on tropical coral cays at Coringa-Herald National Nature Reserve (Batianoff *et al*., 2008b). For example, the nutrient levels of seashore/beach ridge soils were much lower than those of the interior soils. The average values of organic carbon, total nitrogen, phosphorus, and potassium for all landscapes in the Capricornia Cays are however, well below the levels recorded at Coringa-Herald National Nature Reserve (Batianoff *et al*., 2008b).

Table 6-1. Comparison of soil properties at depth for different habitats.

Habitat	Depth (cm)	pH	EC (dS/m^2)	TN (wt%)	OC (wt%)	Colwell-P (mg/kg)	Ca (cmol $^{(+)}$/kg)	K (cmol $^{(+)}$/kg)
Unvegetated beaches	0-20	9.02	0.18	0.13	1.98	79.71	11.76	0.06
Vegetated seashores	0-20	9.25	0.14	0.05	2.05	66.47	10.94	1.20
	C-horizon	9.44	0.10	0.04	0.90	59.38	11.72	2.03
Beach ridges soils	0-20	8.54	0.31	0.23	3.25	247.91	10.65	0.09
	20-40	8.96	0.18	0.09	2.61	95.47	9.45	0.03
	40-60	9.22	0.10	0.07	2.25	76.33	9.52	0.02
	C-horizon	9.46	0.06	0.02	2.42	65.24	8.56	0.01
Interior plains	0-20	7.98	0.37	0.60	3.77	541.49	14.17	0.19
	20-40	8.27	0.25	0.22	4.37	323.23	10.04	0.10
	40-60	8.42	0.25	0.22	3.70	291.00	9.96	0.08
	60-80	8.54	0.23	0.14	4.17	261.09	9.64	0.06
	80-100	8.82	0.26	0.13	3.12	161.26	9.05	0.02
	C-horizon	8.05	0.84	0.13	3.24	55.00	12.66	0.06
Disturbed interior plains soils	0-20	7.86	0.36	0.55	3.94	639.95	16.68	0.16
	20-40	7.92	0.41	0.40	3.79	481.85	10.68	0.13
	40-60	8.01	0.43	0.72	3.20	545.25	9.92	0.08
	C-horizon	8.96	0.08	0.07	2.23	103.64	7.64	0

pH = soil pH, OC = organic carbon, TN = total nitrogen, Colwell-P = phosphorous, Ca = calcium, and K = potassium

6.3.1 Soil pH

The seashore and beach ridge surface soils were the most alkaline of all samples (Table 6-1). The least alkaline soils were the ex-*Pisonia* herbland areas on Tryon Island (pH 7.73), which are now covered by *Solanum americanum, Euphorbia cyathophora* and *Cenchrus echinatus*. Figure 6-1 and Table 6-1 indicate that seashore/beach ridge soil group pH values are generally higher than the interior soils.

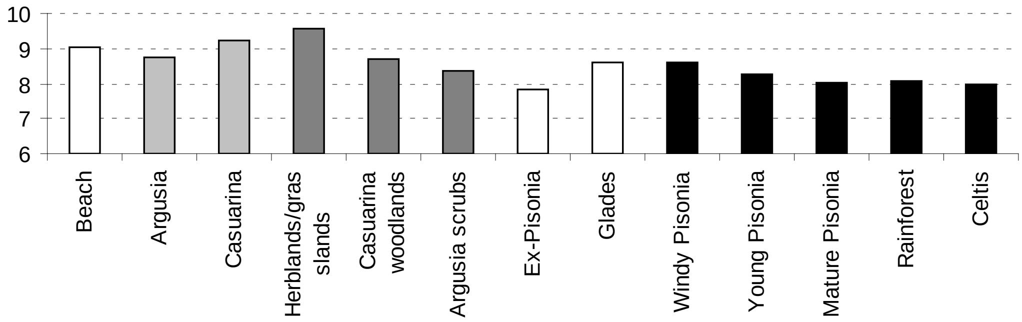


Figure 6-1. Average pH of surface soils (0–20 cm) of different communities and habitats.

	Unvegetated beach
	Vegetated seashore
	Beach ridges

	Interior plains
	Disturbed interior plains

6.3.2 Organic Carbon

All of the surface soils had organic carbon concentrations between 0.9 and 4.4%. The highest values were recorded from the interior lowland areas with lower values from beach the seashore and the beach ridge soils (Figure 7-2).

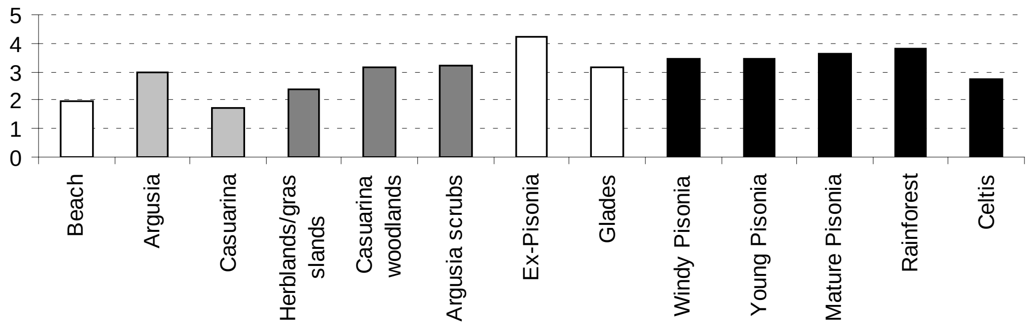


Figure 6-2. Mean organic carbon values (% by weight) of surface soils (0–20 cm) of different communities

	Unvegetated beach
	Vegetated seashore
	Beach ridges

	Interior plains
	Disturbed interior plains

6.3.3 Total Nitrogen

Total nitrogen was generally highest for the interior communities and highest under mature *Pisonia* closed-forest (Figure 6-3).

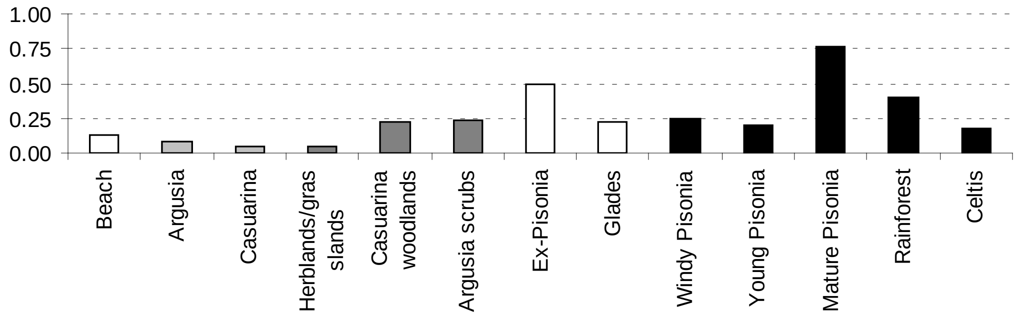


Figure 6-3. Mean total nitrogen values (% by weight) of surface soils (0–20 cm) of different communities

	Unvegetated beach
	Vegetated seashore
	Beach ridges

	Interior plains
	Disturbed interior plains

6.3.4 Phosphorus

Mean phosphorus concentrations are given in Figure 6-4. The phosphorus levels are relatively high for all forested interior soils. The values for the ex-*Pisonia* soils on Tryon Island are high, which could be phosphorus released from the dead *Pisonia grandis* trees. In comparison the areas of glades, newly established *P. grandis* and *Celtis paniculata* contain low levels of phosphorus. These areas also have few nesting seabirds compared to mature *P. grandis* forests and *Argusia argentea* scrubs.

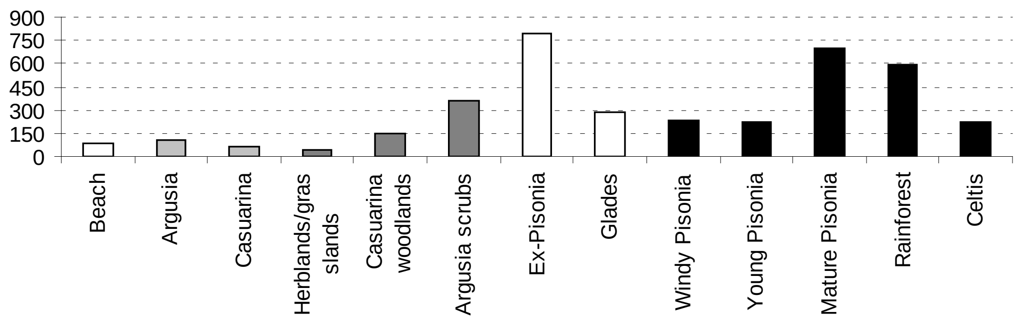


Figure 6-4. Mean phosphorous (Colwell-P) values (mg/kg) of surface soils (0–20 cm) of different communities

	Unvegetated beach
	Vegetated seashore
	Beach ridges

	Interior plains
	Disturbed interior plains

6.3.5 Potassium

The potassium values for similar habitats were variable. For example, the values in *Casuarina equisetifolia* varied by up to 11% across different sites. In general the highest potassium levels were recorded in the mature *Pisonia* forest. These communities also had the highest number of nesting seabirds.

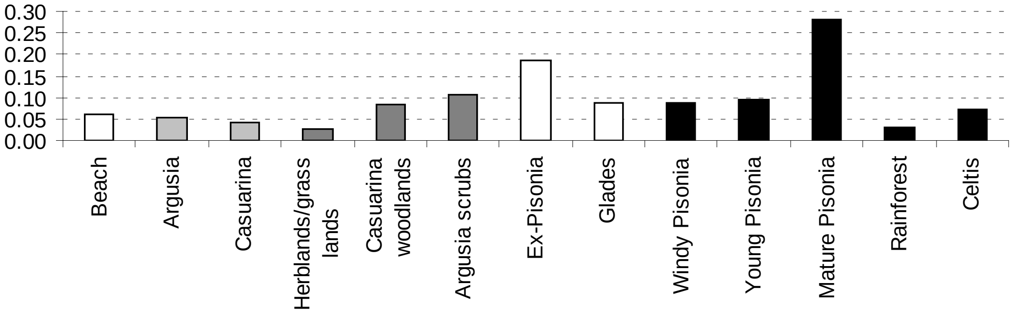


Figure 6-5. Mean potassium values (cmol (+)/kg) of surface soils (0–20 cm) of different communities

(white)	Unvegetated beach
(light grey)	Vegetated seashore
(dark grey)	Beach ridges

(black)	Interior plains
(white)	Disturbed interior plains

6.4 *Pisonia* dieback at Tryon Island

Some soils on the Capricornia Cays have been extensively disturbed by natural and anthropogenic activities. Tryon Island lost about 5 ha of *Pisonia grandis* rainforest cover from 1991-2001 as a result of scale insect attack. Much of this area has been replanted with *Pisonia* but weeds such as **Solanum americanum*, **Euphorbia cyathophora* and **Cenchrus echinatus* were common in some areas at the time of this survey.

At the time of this survey, the surface soils are predominantly fine to very fine textured, with no leaf litter or coral fragments, and a high degree of decomposition resulting in a dark brown soil colour. As depth increases, soil colour lightens to light – medium brown with a higher coarse grain component recorded at 40–60 cm in depth. Pink coloured sand was reached at 80 cm indicating the 'C-horizon'. Generally, higher levels of organic carbon, total nitrogen, available phosphorus and potassium were recorded for the ex-*Pisonia* areas than the mature/old-growth *Pisonia* areas. Nutrient levels were similar throughout the entire 80 cm soil profile.

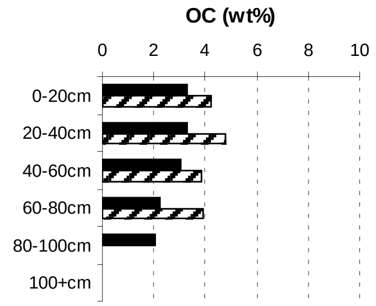
In comparison, the areas formerly covered by *Pisonia* vegetation at SW Coringa Islet at Coringa-Herald National Nature Reserve now feature native herbs and shrubs species such as *Ipomoea macrantha, Abutilon albescens* and *Achyranthes aspera* (Batianoff *et al*., 2008b). The pH and nutrient levels at various depths are provided in figure 6-6 for soils on Tryon Island and Coringa-Herald National Nature Reserve for areas in which *Pisonia* dieback had occurred. Soil nutrient levels were generally higher at Coringa-Herald National Nature Reserve (Batianoff *et al*., 2010b) than at Tryon Island. The soils in ex-*Pisonia* areas at SW Coringa and Tryon had lower levels of all nutrients than the healthy mature/old-growth forests.

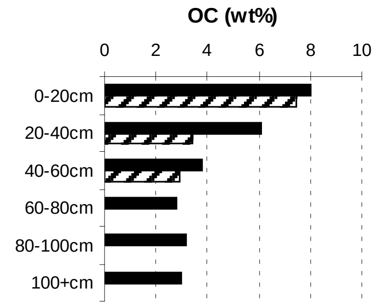
Table 6-2. Soil chemical properties on Tryon Island and Coringa-Herald National Nature Reserve in areas with *Pisonia grandis* cover (Pis) and those that have lost their *Pisonia* cover (Ex).

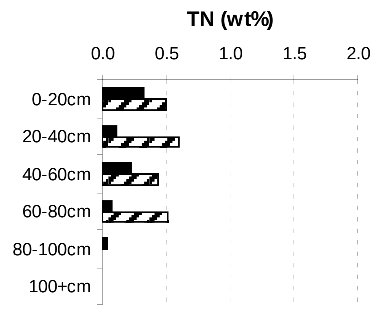
	pH		TN (Wt%)		OC (Wt%)		Colwell-P (mg/kg)		Ca (cmol(+)/kg)		K (cmol(+)/kg)	
Depth	Pis.	Ex	Pis.	Ex	Pis.	Ex	Pis.	Ex	Pis.	Ex	Pis.	Ex
Tryon Island												
0-20cm	7.95	7.82	0.32	0.50	3.27	4.20	248	790	8.88	11.92	0.06	0.19
20-40cm	7.93	7.78	0.11	0.60	3.27	4.81	206	660	8.06	12.38	0.08	0.22
40-60cm	8.03	7.83	0.22	0.44	3.07	3.88	169	847	7.98	11.56	0.04	0.13
60-80cm	8.69	7.76	0.08	0.51	2.26	3.89	114	719	7.56	10.86	0.01	0.17
80-100cm	9.47	n/a	0.04	n/a	2.07	n/a	67	n/a	7.99	n/a	0.00	n/a
100+cm	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Coringa-Herald National Nature Reserve												
0-20cm	7.50	8.16	1.55	1.14	7.99	7.42	1051	964	27.31	20.69	1.92	0.44
20-40cm	7.75	8.76	1.19	0.39	6.11	3.41	994	630	24.79	12.99	1.04	0.11
40-60cm	7.89	8.99	0.53	0.37	3.78	2.94	875	538	19.29	12.22	0.57	0.08
60-80cm	8.52	n/a	0.20	n/a	2.78	n/a	488	n/a	14.28	n/a	0.15	n/a
80-100cm	8.06	n/a	0.40	n/a	3.16	n/a	822	n/a	20.64	n/a	0.65	n/a
100+cm	8.54	n/a	0.01	n/a	2.98	n/a	397	n/a	13.95	n/a	0.25	n/a

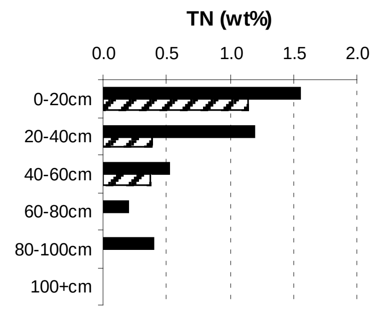
TRYON ISLAND

CHNNR









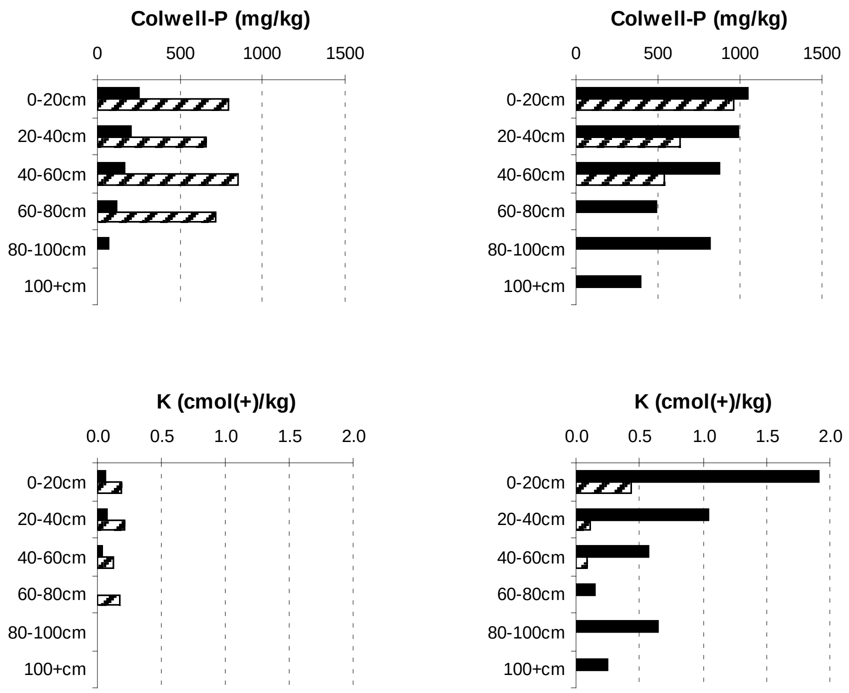


Figure 6-6. Soil chemical properties in areas of old-growth *Pisonia* (solid bars) and herblands previously forested by *Pisonia* (hatched) on Tryon Island and Coringa-Herald National Nature Reserve (CHNNR).

6.5 Natural glades within *Pisonia* stands

Natural tree falls within forested areas create “glades” (refer section 5.2.1). These have different soil chemistry compared to intact forested areas. A comparison of soils from natural glades was made with mature/old-growth *Pisonia grandis* soils from North West and Masthead Islands (Table 6-3). Old-growth and glade areas at Coringa-Herald National Nature Reserve are also included in the comparison.

The depth of soil is less in glade areas than forested areas. Soil in forested areas was recorded beyond 100 cm in depth, whereas in the glades soils reached a maximum depth of 80 cm. Soil pH values at the Capricornia Cays and Coringa-Herald National Nature Reserve are more alkaline in glades than forests. The levels of all key nutrients are lower in glades than in the mature/old-growth forests.

Table 6-3. Comparison of soil chemical properties at depth for all *Pisonia* communities (Pis) and glades in *Pisonia* communities (G)

	pH		TN (Wt%)		OC (Wt%)		Colwell-P (mg/kg)		Ca (cmol(+)/kg)		K (cmol(+)/kg)	
Depth	Pis	G	Pis	G	Pis	G	Pis	G	Pis	G	Pis	G
All Capricornia Cays												
0-20cm	8.0	8.6	0.6	0.2	3.7	3.2	579	284	14.0	11.8	0.2	0.1
20-40cm	8.4	8.7	0.3	0.2	3.7	4.1	406	197	11.5	11.3	0.2	0.1
40-60cm	8.4	8.7	0.3	0.2	3.5	3.7	359	192	11.1	12.1	0.1	0.1
60-80cm	8.6	9.1	0.2	0.1	3.5	4.5	298	108	10.9	10.0	0.1	0.0
80-100cm	8.5	n/a	0.1	n/a	3.2	n/a	143	n/a	10.6	n/a	0.1	n/a
100+cm	8.1	n/a	0.1	n/a	3.2	n/a	55	n/a	12.7	n/a	0.1	n/a
NE Herald glades and SE Magdelaine mature/old-growth *Pisonia* at CHNNR												
0-20cm	7.50	8.4	1.55	0.2	7.99	3.1	1051	594	27.31	13.4	1.92	0.08
20-40cm	7.75	8.4	1.19	0.2	6.11	2.8	994	608	24.79	13.3	1.04	0.06
40-60cm	7.89	8.9	0.53	0.1	3.78	2.7	875	225	19.29	13.0	0.57	0.04
60-80cm	8.52	n/a	0.20	n/a	2.78	n/a	488	n/a	14.28	n/a	0.15	n/a
80-100cm	8.06	n/a	0.40	n/a	3.16	n/a	822	n/a	20.64	n/a	0.65	n/a
100+cm	8.54	n/a	0.01	n/a	2.98	n/a	397	n/a	13.95	n/a	0.25	n/a

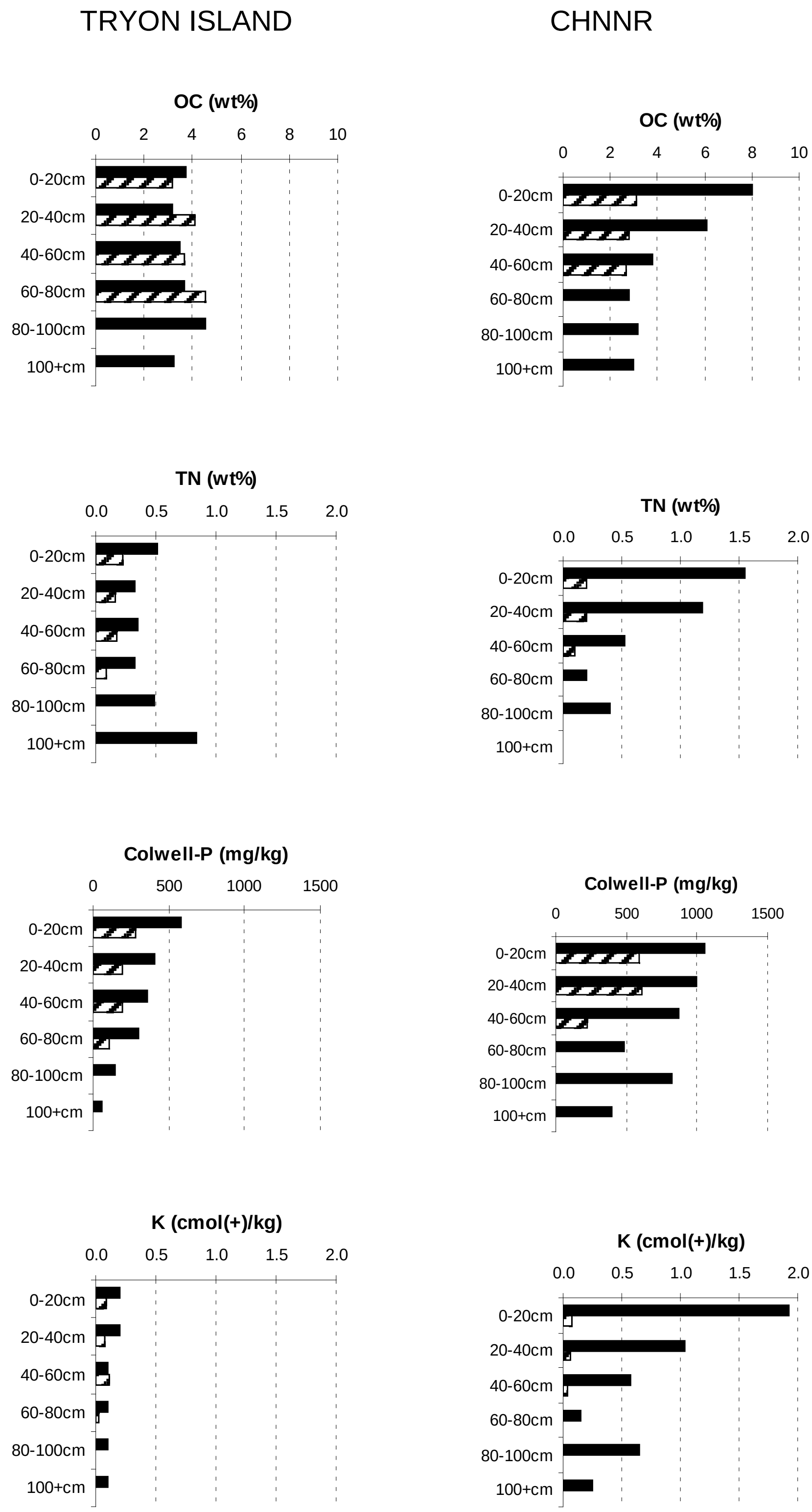


Figure 6-7. Comparison of soil chemical properties in old-growth *Pisonia* (solid bars) and ex-*Pisonia* herblands (hatched bars) on Tryon Island & Coringa-Herald National Nature Reserve (CHNNR).

6.6 Soil condition overview

The soil nutrient levels of the Capricornia Cays are almost half the values of those found at Coringa-Herald Cays (Batianoff *et al*. 2010b). Many authors have described atoll soils (including coral cays) as having a low nutrient status. Empirically, P and N and occasionally K were recorded in this study at very high levels. However, pH values and calcium carbonate bonding particularly with P may produce poor nutrient availability (Morrison, 1990). According to Ashford and Allaway (1982), the mycorrhizal association of *Pisonia grandis* assists in the uptake of nutrients by plant roots.

The physical and chemical characters of coral cay soils are determined by the origin of the parent material, the physical environment (wind, waves, aerosols), and the biological interactions (e.g. vegetation – nesting seabirds and turtles) taking place within the physical environment. The rate of development of inceptic coral calcarosols is dependent on the amount of organic matter available. Organic content is essential for calcareous soils to assist in nutrient cycling, nutrient retention and water retention (Morrison, 1990). Rodgers (1994) describes deposition of additional nutrients to soils from the atmosphere (aerosols), from the sea (dissolved nutrients) and from the marine biosphere (e.g. bird guano, fish).

The terrestrial flora of cays concentrate nutrients in their woody tissues, especially in the growing tips, fruit and wood (Rodgers, 1994). The higher nutrient values in the interior soils reflects the higher biomass of woody plant tissues (Rodgers, 1994). Following the death of plants, such as *Pisonia grandis*, nutrients are mobilised during the decomposition of woody tissues and plant litter. Humus acts as a nutrient-retaining and dispersing agent (Rodgers, 1994). After release, these nutrients may enter the soil, and/or be leached into the freshwater table.

The transfer of nutrients from the litter of surface soil by the process of bioturbation by wedge-tailed shearwaters *Puffinus pacificus* (Bancroft *et al*., 2005) may exacerbate the process of decomposition, and may enrich the ‘A’ horizon. This process of soil mixing assists in the capture of nutrients from the marine ecosystems as aerosols, marine debris, guano and plant litter. However, for bioturbation to occur the habitats need to be suitable for wedge-tailed shearwaters – that is, the soils must be well-compacted with a high proportion of fine roots to stabilise burrows. This represents a symbiotic relationship; the trees provide a suitable habitat for birds, and the birds assist in soil development increasing the availability of nutrients and thereby allowing a larger biomass to be obtained.

PART C. Conservation management

7 Current threats to vegetation

7.1 *Pulvinaria urbicola*

Since 1993, outbreaks of the scale insect *Pulvinaria urbicola* have been significantly affecting the health of *Pisonia* forests on Australian and other islands throughout the species' global range. Although outbreaks may be due to natural fluctuations in the number of scale insects and their natural enemies, the cause of outbreak events is yet to be fully understood. Ants, in some cases introduced ants, exacerbate all outbreaks (O'Neill *et al*., 1997; Olds *et al*., in prep.). From 1993 to 2000, over 90% of the *Pisonia* forest at Tryon Island within the Capricornia Cays National Park was destroyed by scale insect. Significant changes to SW Coringa Islet's *Pisonia grandis* vegetation have resulted from infestations by scale insects.

7.2 Climate variability

The key climate variability elements that influence wildlife include altered rainfall patterns, increased ambient temperatures, increased variation in wind and cyclonic activities and increased atmospheric CO_2. Changes to oceanic conditions such as rises in sea level, sea surface temperatures and ocean acidification are also critical as the terrestrial ecology of coral cays is directly linked with marine ecosystems. Coral reefs are likely to be transformed by the mid to the late century with lower density of both soft and hard corals and a dominance of fleshy micro algae and herbivorous fishes (Anthony and Marshal 2009). Hobday *et al*. (2006) rank the eastern central marine domain as the most vulnerable marine domain in Australia, and Williams *et al*. (2012) state that the greatest changes to coral reefs are likely to be in the inshore and southern Great Barrier Reef.

Summer temperatures at the Capricornia Cays have increased for both the minimum (+0.6ºC, R^2=0.57) and maximum (+1.0ºC, R^2=0.57) temperatures since 1958 (Table 2-3). The duration of droughts has increased from 3–4 years (1940–1991) to 3–7 years (1992–2007). The increased temperature and duration of droughts threaten the current vegetation and other natural values of the Capricornia Cays. As the study area represents the southern-most coral cays in Australia, distributional shifts of coral-cay specific species from tropical areas are most likely to occur (Turner and Batianoff, 2007). The new arrivals in time may change the character of the region. Changes to seabird diversity and populations, coral reef quality, and the climate experienced at the Capricornia Cays will affect vegetation patterns and conditions.

Under elevated CO_2 concentrations, vegetation will have improved water use efficiency by reducing stomatal conductance, known as the 'CO_2-fertilisation effect' (Hughes, 2003; Lovejoy & Hannah, 2005; Turner & Batianoff, 2007). The specific CO_2-fertilisation effect on plants growing on coral cays, such as the Capricornia Cays is not known. However, the benefits of elevated CO_2 on plant growth will depend on water and nutrient availability (Korner *et al*., 2006). According to Hughes (2003), under elevated CO_2 conditions, the competitive regime between C_3 and C_4 species may give an advantage to woody shrubs under dry conditions.

The major impact of climate variability on the vegetation of the Capricornia Cays may arise from the unknown consequences of trophic level interactions such as the combined effects of insect damage, loss of soil nutrients, loss of seabird input, and diminishing levels of freshwater lenses. Loss of vegetation has been reported to coincide with declines in breeding seabird numbers on the Sudbury and Gannet Cays in the Great Barrier Reef (Turner & Batianoff, 2007). *Pisonia grandis* is dependent on the input of nutrients by seabirds, and presence of freshwater lenses. Its future survival may depend on the projected benefits of the 'CO_2-fertilisation effect' on one hand, and the potential diminishing quantity of nutrients and freshwater on the other. As *Pisonia* and *Argusia* provide the key breeding habitats for arboreal-breeding seabirds, the loss of *Pisonia* forest may trigger tropical seabird abandonment of northern breeding habitats. That is, some seabirds may migrate south in search of new breeding opportunities (Hughes 2003).

7.3 Plant resilience and vegetation changes

Some stress-tolerant plants survive dry periods by using water stored in plant tissues and/or perennial roots. For example, *Tribulus cistoides* and *Boerhavia* spp. use large taproots as storage organs and/or perennial propagules, and *Portulaca oleracea* has fleshy stems and leaves that store water. During drought conditions, ruderal or short-lived species (e.g. the grasses and *Abutilon albescens*), which produce large amounts of seed, survive in the soil seed bank. A higher incidence of severe droughts may favour herbaceous vegetation. Adaptations of rainforest species (e.g. *Pisonia grandis*) to dry conditions include the senescence (loss of leaves), and developing deeper roots to colonise central areas with better access to freshwater lenses. On the other hand, smaller trees such as *Cordia subcordata* survive during prolonged dry periods by loss of its main stems, only to recover during wet conditions from basal re-sprouting. Under drought conditions freshwater lenses become brackish and decrease, creating greater moisture stress for woody island plant life (Stoddart & Walsh, 1992; Turner & Batianoff, 2007). Dry periods may facilitate the replacement of rainforest species such as *P. grandis* by short-lived shrubs and/or short-lived herbaceous plants and grasses (Turner & Batianoff, 2007).

Pisonia grandis expands its local populations during wet seasons through vegetative growth. The stem layering by *P. grandis* is considered as a competitive survival strategy that assists the species to cope in a highly variable climate. It is also postulated that with increased moisture and longer "wet" seasons, *P. grandis* may be well adapted to colonising new islands within the Capricornia Cays. Drifting seeds and sprouting plants favoured by wetter conditions in the supra-littoral zone may re-colonise newly deposited sands. However, their survival depends on the intensity of disturbance caused by nesting turtles and grazing crabs (Batianoff *et al*., 1993). Plant and other wildlife species richness may increase under wetter conditions because conditions are more conducive to the establishment/survival of newly arrived species.

7.4 Exotic plant species

Objectives for the management of the Capricornia Cays National Park and National Park (Scientific) are to conserve natural habitats and wildlife, whilst not limiting use for recreation and tourism (QPWS, 2000). Recognising key areas on which to concentrate conservation management efforts is a priority in maintaining natural values at the Capricornia Cays. Determining the status of taxa is a critical aspect of plant conservation. The construction of an accurate regional checklist provides data for management of weeds. The flora of the Capricornia Cays currently includes 66% exotic species, 98% of which are infrequent or rare – making their management more achievable.

The abundance of exotic species on certain islands poses a threat to other islands. Some key weed species have been identified, predominantly from high-use, highly disturbance islands such as Lady Elliot Island. These species (Table 7-1) would be best eradicated and/or contained so as not to compromise native species diversity on other islands within the Capricornia Cays group. Species declared under the Land Protection (Pest and Stock Route Management) Regulation 2003 include one Class 3 weed (**Lantana camara*) and two Class 2 weeds (**Opuntia stricta* and **Bryophyllum delagoense*). Several species are part of the 200 most invasive naturalised species of South East Queensland (Batianoff & Butler, 2002). Efforts to eradicate key weed species at Heron Island and One tree Island have shown that vigilance and a proactive approach to conserving native biodiversity pays off.

Table 7-1. Comments on the major naturalised species in the Capricornia Cays

Family, taxa, common name	LF	Weediness	No. islands	Management recommendations
AGAVACEAE				
**Agave americana* (century plant)	S	H/EW	1	Eradicate with high priority
**Agave sisalana* (sisal hemp)	S	H/EW	1	Eradicate
APOCYNACEAE				
**Catharanthus rosea* (periwinkle)	H	H/EW	1	Control, seed dispersed by ants
ASTERACEAE				
**Calyptocarpus vialis* (creeping cinderella weed)	aH	m/ew	1	Control
BRASSICACEAE				
**Cakile edentula* (American sea rocket)	aH	m/ew	13	Control, ranked 141
CACTACEAE				
**Hylocereus undatus* (moonlight cactus)	H	H/EW	1	Eradicate
**Opuntia stricta* (common prickly pear)	S	H/EW	2	Eradicate, C2 declared weed
CAESALPINIACEAE				
**Senna pendula* var. *glabrata* (Easter cassia)	ST	m/ew	1	Control, ranked 45
COMMELINACEAE				
**Tradescantia* spp. (wandering Jews)	H	m/ew	1	Control, ranked 87
CONVOLVULACEAE				
**Ipomoea cairica* (coastal morning glory)	V	m/ew	2	Control, ranked 28
**Ipomoea indica* (purple morning glory)	V	m/ew	2	Control, ranked 40
CRASSULACEAE				
**Bryophyllum delagoense* (mother-of-millions)	H	H/EW	1	Eradicate – C2 declared weed, ranked 3
**Bryophyllum pinnatum* (resurrection plant)	H	m/ew	1	Control – ranked 47

Family, taxa, common name	LF	Weediness	No. islands	Management recommendations
DRACAENACEAE				
**Sansevieria trifasciata* (mother-in-law's tongue)	H	m/ew	1	Control, ranked 195
EUPHORBIACEAE				
**Euphorbia cyathophora* (dwarf poinsettia)	aH	H/EW	3	Control, ranked 180
LAMIACEAE				
**Plectranthus amboinicus* (soup mint)	H	m/ew	1	Control
PASSIFLORACEAE				
**Passiflora suberosa* (cork passionflower)	V	m/ew	2	Control, ranked 37
POACEAE				
**Cenchrus echinatus* (Mossman river grass)	aH	ew	9	Control, nuisance weed, ranked 178
**Eleusine indica* (crowsfoot grass)	aH	ew	7	Control, ranked 112
**Megathyrsus maximus* (guinea grass)	H	H/EW	3	Control, ranked 20
**Stenotaphrum secundatum* (buffalo grass)	H	m/ew	2	Control, ranked 187
**Urochloa subquadripara* (green summer grass)	H	m/ew	2	Control
SOLANACEAE				
**Capsicum frutescens* (bird's eye chilli)	H	m/ew	1	Control
VERBENACEAE				
**Lantana camara* (lantana)	S	H/EW	1	Eradicate - Ranked 1, C3 declared

Weediness: H/EW = high impact invasive environmental weed; m/ew = moderate impact invasive environmental weed

Ranking as in Batianoff & Butler, 2002; C2 and C3 are Class 2 and Class 3 pests listed under the Land Protection (Pest and Stock Route Management) Regulation 2003.

Concluding overview

1. Vegetation mapping has been completed for fifteen islands. This is an invaluable resource for regional conservation planning and management.
2. The vegetation maps have subsequently been used to develop regional ecosystem mapping and comprehensive technical descriptions for the region.
3. An accurate floristic inventory was made for each island. These inventories provide baseline data for monitoring floristic changes, and the rate of changes due to natural and/or human disturbances on each island.
4. The soil analyses for the Capricornia Cays are difficult to interpret at a regional level due to lack of data from other coral cays. Most nutrient levels are well below those found for the Coringa-Herald Cays.
5. Continued containment and eradication of environmental weeds will help safeguard natural values of native vegetation and wildlife (Table 7-1)
6. Awareness of the environmental values would be enhanced by providing an identification guide of wildlife recorded at Capricornia Cays.
7. The unique values of the Capricornia Cays should continue to be promoted. Linkages between coastal scientists, resort operators and the general public should be pursued to improve the understanding of the unique biodiversity and promote quarantine practices.
8. Active plant conservation management should continue. This includes maintenance/ revegetation of degraded areas, weedy areas and camping grounds with suitable indigenous species. *Pisonia grandis* readily drop branches so should not be used in replantings near camping grounds. Suitable trees for providing shade near campsites include *Ficus rubiginosa, Celtis paniculata*, and *Cordia subcordata*.

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APPENDICES

Appendix A. Inventory checklist of the Capricornia Cays flora: 2007–08

Species Name	Family	LF	Coral Cay															Total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Abutilon albescens	Malvaceae	S		F	F	I	I	I	I	I	A	X	I	A	A	A	A	14
**Acetosa vesicaria*	Polygonaceae	aH															R	1
Achyranthes aspera	Amaranthaceae	aH	I	I	I	I	I	R	I	I	F	X	I	I	F	I	F	15
**Agave americana*	Agavaceae	S															I	1
**Agave attenuata*	Agavaceae	S															R	1
**Agave sisalana*	Agavaceae	S															I	1
**Ageratum conyzoides*	Asteraceae	aH															I	1
**Aloe arborescens*	Asphodelaceae	S															I	1
**Aloe parvibracteata*	Asphodelaceae	S															I	1
**Alternanthera pungens*	Amaranthaceae	aH															F	1
**Amaranthus blitum*	Amaranthaceae	aH									R							1
**Amaranthus viridis*	Amaranthaceae	aH		I	I			I								I	I/F	5
#Araucaria cunninghamii var. *cunninghamii*	Araucariaceae	T															R	1
**Argemone ochroleuca* subsp. *ochroleuca*	Papaveraceae	aH	I					R					X		R	R	I	6
Argusia argentea	Boraginaceae	ST	F	A	F	I	A	F	F	A	A	X	F	F	I	F	A	15
**Bidens pilosa*	Asteraceae	aH	R	I				R				X	I	R	F	F	I	9
Boerhavia albiflora var. *heronensis*	Nyctaginaceae	H	I	I	I	I		I	I	I	F	F	I	I	A	I	A	14
Boerhavia sp. (Bargara L. Pedley 5382)	Nyctaginaceae	H															I	1
**Brassica napus*	Brassicaceae	aH															R	1
**Bryophyllum delagoense*	Crassulaceae	H															F	1
**Bryophyllum pinnatum*	Crassulaceae	H															F	1
Caesalpinia bonduc	Caesalpiniaceae	S			R							F		R		R		4
**Cakile edentula*	Brassicaceae	aH	F	F	F	F	F	I	I	I	I	X		F		I	I	13

Species Name	Family	LF	Coral Cay															Total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
**Calophyllum inophyllum*	Clusiaceae	ST			VR													1
**Calyptocarpus vialis*	Asteraceae	aH						I										1
Canavalia rosea	Fabaceae	V			R					I	A		I	I	R	I	A	8
**Capsella bursapastoris*	Brassicaceae	aH						I									I	2
**Capsicum frutescens*	Solanaceae	H															I	1
**Carica papaya*	Caricaceae	ST															R	1
Cassytha filiformis	Lauraceae	V	I	I	I			I	I	I								6
Casuarina equisetifolia subsp. *incana*	Casuarinaceae	T	F	F	F	F	I	F	R	F	I	F	I	A	I	F	A	14
**Catharanthus roseus*	Apocynaceae	H															I	1
Celtis paniculata	Ulmaceae	T		I	I	R		I	I	F								6
**Cenchrus echinatus*	Poaceae	aH		F	I	I	I	I		I					R	R	I	9
Chamaesyce atoto	Euphorbiaceae	aH		R	I		I/R		I	I		X						6
**Chamaesyce hirta*	Euphorbiaceae	aH			R			R									I	3
**Chamaesyce hyssopifolia*	Euphorbiaceae	aH						R										1
**Chamaesyce prostrata*	Euphorbiaceae	aH						I			R					R	F	4
**Chenopodium murale*	Chenopodiaceae	aH															R	1
**Chloris gayana*	Poaceae	H															I	1
#Chloris ventricosa	Poaceae	aH															R	1
**Citrullus lanatus* var. *lanatus*	Cucurbitaceae	aH														R		1
**Citrus sp.*	Rutaceae	ST														R		1
Clerodendrum inerme	Lamiaceae	S								R								1
**Commelina benghalensis*	Commelinaceae	H															I/R	1
Commicarpus insularum	Nyctaginaceae	V		A/F	R	A			F	F	F	I						7
**Conyza bonariensis*	Asteraceae	aH		I				I						R		I		4
**Conyza sumatrensis*	Asteraceae	aH		I	I			R					X				F	5
Cordia subcordata	Boraginaceae	ST		I		I		I		I								4
**Cyclospermum leptophyllum*	Apiaceae	aH						R									I/R	2

Species Name	Family	LF	Coral Cay															Total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
**Cynodon dactylon* var. *dactylon*	Poaceae	H				R		I									F	3
**Cynodon nlemfuensis* var. *nlemfuensis*	Poaceae	H						R										1
#Cyperus gracilis	Cyperaceae	aH															I	1
#Dentella repens	Rubiaceae	aH															I	1
#Digitaria bicornis	Poaceae	aH															I	1
**Digitaria ciliaris*	Poaceae	aH		I		R		I			R					R	F	6
**Eleusine indica*	Poaceae	aH		F	I	I		F			I					R	F	7
**Emilia sonchifolia*	Asteraceae	aH															I	1
**Eragrostis minor*	Poaceae	aH															I	1
**Eragrostis tenuifolia*	Poaceae	aH															F	1
**Euphorbia cyathophora*	Euphorbiaceae	aH		F				I									A	3
Euphorbia tannensis subsp. *tannensis*	Euphorbiaceae	aH		I	I	I	I	I	I	I				I		I	I	10
Ficus opposita	Moraceae	ST		I	I	I	I	I	F	F			X	F	I	I	I	12
Ficus rubiginosa	Moraceae	T		I	I												I	3
**Gomphrena celosioides*	Amaranthaceae	aH															I	1
Hernandia nymphaeifolia	Hernandiaceae	T			VR													1
#Hibiscus tiliaceus	Malvaceae	T															R	1
#Hydrocotyle acutiloba	Apiaceae	aH															I	1
**Hylocereus undatus*	Cactaceae	H															I	1
**Ipomoea cairica*	Convolvulaceae	V										X					I	2
**Ipomoea indica*	Convolvulaceae	V														I	I	2
Ipomoea macrantha	Convolvulaceae	V		I	R	I	I/R			I	F	X				R	R	9
Ipomoea pes-caprae subsp. *brasiliensis*	Convolvulaceae	H						R		I	I/R			R		I	I	6
**Lantana camara*	Verbenaceae	S															A	1
**Lepidium didymum*	Brassicaceae	aH			I			R			I/R					R	I	5

Species Name	Family	LF	Coral Cay															Total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Lepidium englerianum	Brassicaceae	aH	I		I		I			I		I						5
**Lepidium virginicum*	Brassicaceae	aH				R		R								R	R	4
Lepturus repens	Poaceae	H	I	I	F	F	F	F	I	F	F	X	F		I	F	F	14
**Malva parviflora*	Malvaceae	H															I	1
**Malvastrum coromandelianum*	Malvaceae	S						R								R	F	3
**Megathyrsus maximus*	Poaceae	H					R	R									I	3
**Mirabilis jalapa*	Nyctaginaceae	H															I	1
**Nerium oleander*	Apocynaceae	S															R	1
**Opuntia stricta*	Cactaceae	S								I							R	2
**Oxalis corniculata*	Oxalidaceae	H															I	1
Pandanus tectorius	Pandanaceae	ST	I	F	I	A	F	F		I/F	I	I		I		F	I/F	12
**Passiflora suberosa*	Passifloraceae	V			I/F												F	2
Pipturus argenteus	Urticaceae	ST		I	I			I		I								4
Pisonia grandis	Nyctaginaceae	T	R	I/F	A	A	A	A	F	A	F	F	F	A	I	A	I	15
**Plantago lanceolata*	Plantaginaceae	aH															I/F	1
**Plectranthus amboinicus*	Lamiaceae	H															I/F	1
Plumbago zeylanica	Plumbaginaceae	H							I/F	R	A	I	F					5
**Poa annua*	Poaceae	aH						I								I		2
Portulaca oleracea	Portulacaceae	H	R	I	I/R		I	F		I	I	X	X	R	A	R	I	13
**Portulaca pilosa* subsp. *pilosa*	Portulacaceae	aH				R		R									I	3
#Pseudognaphalium luteoalbum	Asteraceae	aH		I	I/F		I/F	I		I				R		I	I	8
Salsola kali	Chenopodiaceae	aH							R	I								2
**Sansevieria trifasciata*	Dracaenaceae	H															I	1
Scaevola taccada	Goodeniaceae	ST	F	F	F		I	F	F	F	R	X	X	R				11
#Schefflera actinophylla	Araliaceae	T															I	1
**Senna pendula var. glabrata*	Caesalpiniaceae	ST															R	1
Sesuvium portulacastrum	Aizoaceae	H			R					I	I				I	R		5

Species Name	Family	LF	Coral Cay															Total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
**Sisymbrium irio*	Brassicaceae	aH						I										1
**Sisymbrium orientale*	Brassicaceae	aH	I		F			R						R	R		I	6
**Solanum americanum*	Solanaceae	aH		A	I	I		I		I	F	I	I	I	A	F	F	12
**Solanum lycopersicum* var. *cerasiforme*	Solanaceae	aH			R			R		R								3
**Sonchus oleraceus*	Asteraceae	aH		I	R	R		I			I		X	I	F	I	I	10
Sophora tomentosa subsp. australis	Fabaceae	ST			R			R		I/F								3
**Sorghum bicolor*	Poaceae	aH			R													1
Spinifex sericeus	Poaceae	H			I/R				I	I/F				I				4
Sporobolus virginicus	Poaceae	H		F	I	F	F	F	F	I						F		8
**Stachytarpheta cayennensis*	Verbenaceae	aH															I	1
**Stellaria media*	Caryophyllaceae	aH															I	1
Stenotaphrum micranthum	Poaceae	H		I	I			F		F	F	X	X	I				8
**Stenotaphrum secundatum*	Poaceae	H															F	1
Stephania japonica	Menispermaceae	V								R								1
Suriana maritima	Surianaceae	S			I		F	I		I		X						5
#Terminalia arenicola	Combretaceae	T															I	1
Tetragonia tetragonioides	Aizoaceae	aH									F		I		F	I		4
Thuarea involuta	Poaceae	H	F	I/F	A	A	F	F	F	I		X	X	F		A	F	13
Trachymene cussonii	Apiaceae	aH								R	I			F			R	3
**Tradescantia pallida*	Commelinaceae	H															I	1
**Tradescantia spathacea*	Commelinaceae	H															R	1
**Trianthema portulacastrum*	Aizoaceae	H						R									I	2
Tribulus cistoides	Zygophyllaceae	H		I	I	I	I	I	I	I						R	F	9
**Tridax procumbens*	Asteraceae	aH															I	1
Triumfetta procumbens	Sparrmanniaceae	H												R			R	2
**Urochloa subquadripara*	Poaceae	H						R									F	2

Species Name	Family	LF	Coral Cay															Total
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Wollastonia biflora	Asteraceae	H		F	F	F	F	F	I	I	A	X					I	10
Ximenia americana	Olacaceae	ST		I/R														1
**Zephyranthes candida*	Amaryllidaceae	H															R	1
Total species: 131 spp.	32 families	-	16	38	47	27	23	55	22	42	28	24	20	26	18	39	97	-
Natives: 44 spp.	31 families	-	12	26	33	18	19	24	21	36	20	20	15	19	12	20	21	-
Exotics (*): 77 spp.	33 families	-	4	11	13	9	3	31	1	5	8	4	5	6	6	18	66	-
Mainland natives (#): 10 spp.	10 families	-	0	1	1	0	1	1	0	1	0	0	0	1	0	1	10	-

Status: * = exotic to Australia and coral cays; # = native mainland species, non-indigenous to coral cays.

Life form (LF): T = tree (>5m tall); ST = small tree / tall shrub (2-5m); S = shrub (<2m); H = perennial herb; aH = annual herb; V = vine.

Coral cays: 1 = North Reef; 2 = Tryon; 3 = North West; 4 = Wilson; 5 = Wreck; 6 = Heron; 7 = Erskine; 8 = Masthead; 9 = One Tree; 10 = Hoskyn West; 11 = Hoskyn East; 12 = Fairfax West; 13 = Fairfax East; 14 = Lady Musgrave; 15 = Lady Elliot.

Frequency: A = abundant (>30% of sites); F = frequent (15-30% of sites); I = infrequent (1-15% of sites); R = rare (<1% of sites); VR = very rare (single occurrences).

Appendix B. Area of vegetation communities present on the Capricornia Cays: 2007–08

Coral cays	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A – sandy shores	1.69	4.91	11.90	1.66	3.45	3.64	3.08	6.45	.45	2.85	.46	2.30	2.38	3.67	4.22
B – lithified shores		.30	.59	1.40	.98	1.52	.14	2.24	x	.21	x	x	x	.60	1.34
C – built up or disturbed areas	.04		.10	.21		7.02		.06	.32					.13	3.58
D – shingle shores with sparse-herbland of *Canavalia rosea*									.96		.31	1.7	3.05		.40
E – steep erode coral shores				.50											
FORESHORE BEACH VEGETATION															
1a – **Cakile* ephemeral herbland			x		.59		x					.06			
1b – *Spinifex* open-grassland	x		x				.16	1.04							
1c – *Sporobolus* closed-grassland				x				.41							
1d – Seashore mixed herbland	.38	.84	1.09	.36	x	x	.06	.02	x	x	x	.60	x	.04	.25
1e – Very sparse herbland, mainly sand	.45														
FRONTAL BEACH RIDGE VEGETATION															
2a – *Argusia-Scaevola* open-scrub (littoral scrub)	.41	1.87	.40	.06	2.02	.76	.63	1.51	.54	.05	.20				.92
2b – *Argusia* open-scrub to closed-scrub +/- *Casuarina*	.09	.08	3.11	.07	x	.71	x	x	.08	.34	x	.48	.08	.32	x
INTERIOR RIDGES, SWALES, PLAINS VEGETATION															
3a – *Naturalized grassland/ herblands to open-heath		2.87												1.7	2.83
3b – Ephemeral wetlands									.02				.15	.02	.03
3c – *Sesuvium portulacastrum* herbland									.23				.16		
3d – *Lantana camara* shrubland															5.99
3e – Mown airstrip of *Cynodon dactylon*, *Eragrostis*															5.10

Coral cays	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4 – Mixed herbland to mixed shrubland		x	x		1.08	.43	.28			.42	.11	.06	3.39	.87	x
5a – *Wollastonia biflora* +/- *Abutilon albescens*							.10		1.10			.36	.06		
5b – *Plumbago/ Canavalia/ Lepturus* herbland									.85		.09		9.11		
5c – *Abutilon albescens* shrubland		1.07	.88		.18		.18	.37		.63				1.03	
7 – *Scaevola taccada* open- to closed-scrub	.28		x		.05	x	.21	x		x					x
8a – *Casuarina* woodland to low open-forest	.07	.72	1.20		.29	1.38		.54	.03	1.02	.04	.89	.18	.99	2.44
8b –*C. equisetifolia* woodland with mid-dense shrub layer		.09	2.17			.10		2.81							
8b –*C. equisetifolia* woodland with *Pandanus*				1.1											
9 – *Pandanus tectorius* closed-scrub to low closed-forest	.03	1.10		1.15	.34	x		.27	.05	.44		.07		.54	
10 – *Celtis* low open-forest to closed-forest		.53	1.58					.55							
11a – *Pisonia* closed-scrub to low closed-forest	.01	.33	8.46		.94	.45	1.73	2.19	.91	3.51	1.15	.70	1.98	.52	.15
11b – *Pisonia* old-growth open-forest to closed-forest		1.07	87.71	1.24		5.78		25.79				1.04	.56	10.61	x
12a – *Ficus rubiginosa*. closed-forest		.16	x	x											
12b – *Ficus opposita*. low shrubland													.10		
13 – *Casuarina equisetifolia* and *Pisonia* woodland															15.16
14 – *Ximenia americana* closed-scrub		x													
15 – *Cordia subcordata* low closed-forest		x		x		x		x							

Coral cays: 1 = North Reef; 2 = Tryon; 3 = North West; 4 = Wilson; 5 = Wreck; 6 = Heron; 7 = Erskine; 8 = Masthead; 9 = One Tree; 10 = West Hoskyn; 11 = East Hoskyn; 12 = Fairfax (West); 13 = Fairfax (East);14 = Lady Musgrave; 15 = Lady Elliot. X = area too small to be mapped.

Appendix C. Native plant species suitable for revegetation / regeneration and landscaping at the Capricornia Cays

Plant names	1	2	3	4	5	6	7	Comments
Ground layer (11 spp.)								
Boerhavia albiflora var. *heronensis*	L	M	H	L	U	M	M	Endemic to Capricornia cays; prostrate, tap-rooted, fleshy perennial herb (0.1–0.3 m). Location: seashore & interior. Propagation: fresh seeds. Landscaping: open spaces, low traffic groundcover & novelty gardens.
Canavalia rosea	M	M	M	L	U	L	L	Widespread coastal perennial sprawling stems herb (0.2–1.0 m). Location: seashore/interior. Propagation: seeds & rooted stem cuttings. Landscaping: open space low traffic groundcover.
Lepturus repens	H	H	M	L	U	M	M	Widespread coastal creeping grass (0.3–0.6 m). Location: seashore/interior. Propagation: seeds & rooted stem cuttings. Landscaping: moderate traffic groundcover.
Sesuvium portulacastrum	M	L	L	U	U	M	U	Widespread coastal halophyte; succulent perennial creeping herb (0.1–0.2 m). Location: seashore/interior. Propagation: fresh seed & rooted stem cuttings. Landscaping: open space low traffic groundcover & garden beds.
Spinifex sericeus	H	M	U	U	U	L	U	Widespread perennial beach grass (0.2–0.4 m) with long trailing stems. Location: seashore only. Propagation: seeds & runners/stem cuttings. Landscaping: seashore sand stabilizer.
Sporobolus virginicus	M	M	L	L	U	M	H	Widespread halophyte; perennial creeping grass (0.15–0.35 m). Location: seashore/interior. Propagation: seeds & rooted stem cuttings. Landscaping: exposed salt laden open space lawns, moderate traffic, camping grounds.
Stenotaphrum micranthum	H	M	L	L	U	M	M	Endemic to coral cays; salt tolerant creeping grass (0.1–0.2 m). Location: seashore. Propagation: seed & rooted stem cuttings. Landscaping: low traffic groundcover.
Thuarea involuta	H	H	M	L	L	M	H	Widespread coastal perennial creeping grass (0.1–0.2 m). Location: seashore/interior. Propagation: seeds & rooted stem cuttings. Landscaping: seashore ground cover & semi shade law traffic lawns.
Trachymene cussonii	M	M	U	U	U	M	L	Endemic at Capricornia cays with Southern Limit at Lady Elliot Island; salt tolerant annual herb (0.15–0.3 m). Location: seashore. Propagation: fresh seeds. Landscaping: coral rubble open ground cover & novelty gardens.
Triumfetta procumbens	M	M	L	U	U	L	L	Tropical islands endemic; trailing perennial herb (0.15–0.25 m). Location: seashore.

Plant names	1	2	3	4	5	6	7	Comments
								Propagation: seed rooted stem cuttings. Landscaping: sand stabilizer & novelty gardens.
Wollastonia biflora	M	H	M	L	U	H	U	Widespread robust sprawling perennial herb (0.5–1.5 m). Location: seashore/interior. Propagation: seed & rooted stem cuttings. Landscaping: sand stabilizer, camping grounds and novelty garden beds.
Shrub layer (4 spp.)								
Abutilon albescens	U	L	H	M	U	M	U	Widespread coastal shrub (0.5–2.0 m). Location: interior. Propagation: seed & stem cuttings. Landscaping: open space shrub cover & garden beds.
Clerodendrum inerme	L	M	L	L	U	M	U	Coastal shrub (1.5–2.5 m). Location: seashore. Propagation: seed & stem cuttings? Landscaping: beach front.
Scaevola taccada	M	H	M	L	U	H	U	Widespread salt tolerant, fleshy large-leaved shrub (1.5–3 m). Location: seashore/interior. Propagation: fresh seed & stem cuttings. Landscaping: screening gardens, camping grounds.
Suriana maritima	M	H	M	M	U	M	U	Salt tolerant, fine dense foliage shrub (1.5–2 m). Location: seashore & interiors. Propagation: fresh seed. Landscaping: windbreak, screening, camping grounds & novelty gardens.
Tree layer (13 spp.)								
Argusia argentea	H	H	L	L	U	H	U	Widespread seashore halophyte, silvery dense foliage, small tree (2–6 m). Location: foreshore. Propagation: fresh seed. Landscaping: open space, windbreak, screening gardens & campgrounds.
Calophyllum inophyllum	L	M	L	L	M	M	U	Foreshore tropical large leaved tree (5–20 m). Location: seashore/interior. Propagation: shell removed seed. Landscaping: novelty gardens & esplanades.
Casuarina equisetifolia subsp. *incana*	M	H	L	M	L	H	U	Widespread coastal salt & wind tolerant, tree (6–12 m). Location: seashore/interior. Propagation: seed. Landscaping: wind-break, camping grounds, feature gardens.
Celtis paniculata	U	M	M	H	H	H	U	Rainforest tree (5–15 m). Location: interior. Propagation: fresh seed. Landscaping: esplanades, camping grounds shade cover & novelty gardens, attractive to wildlife.
Cordia subcordata	U	H	L	L	L	H	U	Seashore tree (4–8m). Location: seashore. Propagation: seed. Landscaping: shade, gardens & camping grounds
Ficus opposita	U	L	H	H	M	M	U	Widespread dry scrubs & forest small tree (3–7 m). Location: interior. Propagation: fresh seed. Landscaping: open space,

Plant names	1	2	3	4	5	6	7	Comments
								camping grounds & rainforest gardens; attractive to wildlife.
Ficus rubiginosa	U	L	L	H	H	M	U	Large rainforest tree (8–16 m). Location: interior. Propagation: fresh seed. Landscaping: forests shade cover, gardens, camping grounds, attractive to wildlife.
#Hibiscus tiliaceus	L	M	U	L	U	M	U	Widespread coastal halophyte; Introduced to Lady Elliot Island from mainland, salt tolerant native tree (6–8 m). Location: seashore. Propagation: seed. Landscaping: seashore feature gardens.
Pandanus tectorius	M	H	M	M	L	H	U	Widespread coastal salt and wind tolerant tree (5–10 m). Location: littoral forests. Propagation: fresh seed. Landscaping: open areas, camping grounds & seashore feature gardens.
Pipturus argenteus	U	L	M	H	M	H	U	Fast growing rainforest small tree (2–6 m). Location: interior, Propagation: fresh seed. Landscaping: screening gardens, camping grounds, attractive to wildlife.
Pisonia grandis	U	L	L	H	H	L	U	Tropical large tree (12–20m). Location: interior. Propagation: fresh seed & stem cuttings. Landscaping: rehabilitation, novelty gardens, attractive to wildlife.
Sophora tomentosa subsp*. australis*	L	H	M	L	L	M	U	Seashore small tree (2–4m). Location: beach front forest. Propagation: seed. Landscaping: screening gardens, camping grounds.
Ximenia americana	U	L	M	M	M	M	U	Uncommon offshore, widespread on mainland dry scrubs small tree with eatable fruit (2–4m). Location: interior. Propagation: seed. Landscaping: screening & novelty gardens.
Vines / twiners (2 spp.)								
Commicarpus insularum	U	M	H	M	L	M	L	Uncommon on mainland but widespread at Capricornia cays, vine/twiner (0.3–3m). Location: interior. Propagation: fresh seed. Landscaping: screening in gardens & camping grounds.
Ipomoea macrantha	U	M	M	H	H	M	L	Tropical vine/trailer (0.3–10m). Location: forests & herblands. Propagation: seed. Landscaping: screening in gardens & camping grounds.

Functional groups:

1 = beachfront herblands with & without woody plants; 2 = beachfront woodlands to scrublands (Argusia/Casuarina/Pandanus); 3 = interior herblands to heathlands with & without emergent woody plants; 4 = interior littoral woodlands to open-forests; 5 = littoral rainforests; 6 = resort landscaping/garden beds/camping grounds & 7= resort airstrip & paths groundcover.

Suitability: U = unsuitable; L = low suitability; M = moderate suitability, H = high suitability

Appendix D. Metadata for the mapping of the vegetation communities of the Capricornia Cays, Southeast Queensland

- Digital data (shapefile format) are available from QGIS, http://dds.information.qld.gov.au/dds/
- Technical descriptions and maps (A3 colour) of the vegetation communities of each island overlying aerial photography at a scale of 1:1000-1:5000, are available online (http://www.ehp.qld.gov.au/ecosystems/biodiversity/regional-ecosystems/technical_descriptions.html).

Title: The Vegetation Communities of the Capricornia Cays, Southeast Queensland

Date: 25-05-2012 (revision)

Abstract: Aerial Photo Interpretation completed by V.J. Neldner on overlays to selected 2007 and 2001 photos. Ortho-rectification and GIS by J.A. Kelley. The resulting polygons were refined at an edit scale of about 1:500, to produce a map scale between 1:1000 and 1:2000 depending on the size of the island. The pre-clearing mapping was informed by the 238 sites collected by G.N. Batianoff, G.C. Naylor and D.A. Halford, which are stored in the CORVEG database. Thirteen of the fifteen Capricornia Cays (defined as all islands in the Capricornia Cays NP, Capricornia Cays NP (Scientific), Lady Elliot Island and North Reef Island) were surveyed from August 2007 - September 2008 over five separate trips. Mapping was assisted by scrutiny of the notebooks, vegetation transects and terrestrial photographs of G.N. Batianoff and G.C. Naylor, D.A. Halford's oral description of his terrestrial photographs, and limited information from insect survey sites of the Queensland Museum.

Owner: Department of Science, Information Technology, Innovation and the Arts.

Data / Resource Constraints

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Lineage: The pre-clearing mapping was informed by the 238 sites collected by G.N. Batianoff, G.C. Naylor and D.A. Halford, which are stored in the CORVEG database. Thirteen of the fifteen Capricornia Cays (defined as all islands in the Capricornia Cays NP, Capricornia Cays NP (Scientific), Lady Elliot Island and North Reef Island) were surveyed from August 2007 - September 2008 over five separate trips. Mapping was assisted by scrutiny of the notebooks, vegetation transects and terrestrial photographs of G.N. Batianoff and G.C. Naylor, D.A. Halford's oral description of his terrestrial photographs, and limited information from insect survey sites of the Queensland Museum.

Data Quality

Completeness: Complete for extent of 2007 remnant vegetation communities and pre-clearing of the Capricornia Cays.

Consistency: A test of consistency for vegetation and regional ecosystem unit values (VEG, RE and PERCENT) between the pre-clearing and remnant layers.

Positional accuracy: Aerial photography was captured on 22 November 2007 by QASCO (project QAS 3624c) at 1:4000, and 1:6000 for the larger islands (Heron, Lady Musgrave, North West, Lady Elliot). The full southwest spit of Fairfax West was not captured. For each photo QASCO provided the exposure station (Easting, Northing, Height) but did not provide the rotation angles (Omega, Phi, Kappa). For approximate ortho-rectification, the small tilt angles Omega and Phi were assumed to be zero, and Kappa was calculated from overlapping photos. These approximate results were then refined, wherever possible, by fitting to miscellaneous GPS points collected by G.C.Naylor, D.A.Halford, and V.J.Neldner. GPS point coverage was lacking for Hoskyn, and inadequate for Wilson and North Reef. Some refinements were also made by ortho-rectifying 2001 aerial photography captured by Airesearch Mapping: projects AM875 (30/31 May 2001) and AM881 (29 July 2001) - Hoskyn (1:4000 and 1:5000), Masthead (1:8600), Lady Musgrave (1:6000), North West (1:6000 and 1:10,000).

Attribute accuracy: The pre-clearing mapping was informed by the 238 sites collected by G.N. Batianoff, G.C. Naylor and D.A. Halford, which are stored in the CORVEG database.