FACTORS INFLUENCING VEGETATION

Geology

Given the marked physical and chemical differences between soils developed on basalt and calcarenite it is reasonable to expect equally marked differences between vegetation on these substrates. Although I did not specifically sample to examine this question, various data are available for examination. These are structural data from *Howea forsterana* forests and to a lesser extent from *Drypetes-Cryptocarya* forests. Suitable floristic data are available for Lowland Mixed Forest, and for the detailed distribution of individuals of *Howea forsterana* and *H. belmoreana*. Finally, we can compare more general data on growth form, origin and substrate.

Structural data from *Howea forsterana* forests (Table 5) show a consistent pattern: forests on basalt are richer, higher, have larger basal area and are denser than those on calcarenite. No significance tests are made because sample numbers are too small except in the case of height.

Basal area data from *Drypetes-Cryptocarya* forest (Table 5) show the same pattern. However, despite the marked differences in appearance (more-or-less due to structure) between *Drypetes-Cryptocarya* forest and the Calcarenite Facies (DaCtC) there is considerable overlap in the structural data from each community, summarized in the main vegetation table.

For these two examples (*Howea forsterana* and *Drypetes-Cryptocarya* forests) we can show some structural differences, but further detailed sampling would be necessary to suggest that this is a general situation pertaining to all communities.

The first floristic example comes from Lowland Mixed Forest, a community normally found only on basalt. However, one isolated stand occurs on calcarenite between Signal Point and Neds Beach. Several species normally found only on basalt grow here: *Bubbia howeana, Cleistocalyx fullagari, Randia stipulosa* and *Cyperus brevifolius.* This is the only site where these 'basalt species' occur. *Pandanus forsteri* occurs on calcarenite only here and on dry platy outcrops of calcarenite behind Pebbly Beach. *Howea belmoreana* which is rarely found on calcarenite also occurs here (see below). Were it not for the surface outcrops of calcarenite, I would have predicted that the substrate was basalt.

The second floristic example concerns the relative distribution of *Howea forsterana* and *H. belmoreana* on the two substrates. Perhaps the most persistent myth about the vegetation of Lord Howe concerns the distribution of individuals of *Howea forsterana and H. belmoreana.* Etheridge (1889b) reported "a very remarkable fact in connection with the two lowland species [of palms] . . . wherever the soil is derived from the decomposition of the Coral-sand rock [calcarenite], the Thatch Palm (*K. Forsteriana*) [*Howea forsterana*] exclusively prevails, whilst the appearance of the Curly Palm [*H. belmoreana*] at once indicates a volcanic soil". This had not been observed or at least not stated by either Duff (1882) or Moore (1869a) but Maiden (1898) agreed that "*Kentia Belmoreana* [*Howea belmoreana*] will not grow on the coral sandy ground; it is always found on basalt." In 1940 and 1959, Rabone states "*Howea belmoreana,* the Curly Palm, grows on basalt soil only . . ." but his view is almost certainly based on the earlier opinions of Etheridge and Maiden. Oliver (1917) "paid particular attention to the distribution of the two species of *Howea* . . . and considers there is no foundation in fact for the above quoted statements . . ." (i.e., those quoted above here).

Even in 1974 this apparently perfect disjunction was quoted to me by some island residents. I have seen *Howea belmoreana* on calcarenite in only one place: Neds Beach.

TABLE 5

Quantitative data from forests on calcarenite and basalt

Attribute	Calcarenite		Basalt	
A. *Howea forsterana* (Hf) Forest				
Number of species/site	9.9 ± 5.8	n = 7	11.4 ± 6.8	n = 6
Height (m)	7.1 ± 2.7	n = 158	7.9 ± 4.4	n = 104
Basal area (sq m/ha)	703 ± 193	n = 23	793 ± 133	n = 5
Density (stems/ha)	1712 ± 327	n = 9	1884 ± 406	n = 5
B. *Drypetes australasica-Cryptocarya triplinervis* (DaCt) Forest				
Basal area (sq m/ha)	660 ± 241	n = 7	754 ± 155	n = 10

All figures are means ± standard error of mean based on numbers of samples shown (n). Source: Pickard (1978 recalculated, 1980 and unpublished data).
Hf Numbers of species/site: from sites used for computer analysis, altitude range 0–16 m. Height: from transects specifically for sampling palms. Basal area: measured with glass prism. Density: from circular plots of area 84 sq m.
DaCt Basal area: measured with glass prism.

Early photographs clearly show *H. belmoreana* growing on Signal Point on calcarenite but these stands no longer exist. It also grows on alluvium derived from a mixture of basalt and calcarenite at the western foot of Malabar Ridge. Consequently, I agree with Oliver: *Howea forsterana* occurs on both substrates but is much more abundant (by several orders of magnitude) than *H. belmoreana* on calcarenite. Both these floristic examples show how the apparently sharp differences in some communities on the one substrate are obscured when a wider range of variation is examined.

A broader island-scale floristic comparison is possible using field knowledge of the substrates each species occurs on, the origin of each species (native, endemic and naturalized) and the growth-form (tree, small tree, shrub, twiner, herb, graminoid and fern). The resultant 3-way table (Table 6) can be examined to see the effect of substrate. Most of the analysis that follows is restricted to those species growing on only one substrate and not both.

However it is worth asking whether the *total* numbers of species on basalt and calcarenite follow the empirical power law of island biogeography (MacArthur & Wilson, 1967), viz:

$$S = cA^Z$$

where S = number of species
A = area
c = coefficient
z = parameter

For isolated islands z is usually 0.20–0.35, but for areas within an island it is usually 0.12–0.17. Thus for the total numbers of species on basalt and calcarenite we wish to determine z.

Solving $$\frac{S_c}{S_b} = \left(\frac{A_c}{A_b}\right)^Z$$ for z,

with $S_b = 325$, $S_c = 268$, $A_b = 1188$ and $A_c = 332$, we find that $z = 0.15$.

Clearly then this is in the range given by MacArthur & Wilson (1967) and we can conclude that the *total* numbers of species on each substrate can be predicted from the theory of island biogeography.

However, the picture is more complex when we examine the numbers of species *restricted* to each substrate. There is no reason to believe that these will follow the same power law, and even less reason to believe that the parameter z will be in the same range as for all species. Thus we cannot use the theory of island biogeography to calculate expected numbers of restricted species for purposes of comparisons.

The best way to examine Table 6 is by considering each of the origins separately and using chi-squared tests of independence to detect interactions. For native species we see that the significant interaction (chi-squared statistic 18.8 with 5 d.f.) is due mainly to herbs which are over-represented on basalt. There are no endemics restricted to calcarenite so there is no interaction in this table. With the naturalized species there is no significant interaction (chi-squared statistic 5.0 with 5 d.f.) between substrate and growth-form. This indicates that the individual growth-forms are mostly represented in the ratio of the marginal total, 18:61.

TABLE 6

Three- and two-way tables of substrate, origin and growth-form; and total numbers of species on the substrates

A. Three-way table

		Growth-form							
Origin	Substrate	Tree	Small tree	Shrub	Twiner	Herb	Graminoid	Fern	Total
Native	Basalt	0	0	5	1	7	19	20	52
	Calcarenite	1	0	1	1	6	2	0	11
	Total	1	0	6	2	13	21	20	63
Endemic	Basalt	5	14	11	1	7	5	16	59
	Calcarenite	0	0	0	0	0	0	0	0
	Total	5	14	11	1	7	5	16	59
Naturalized	Basalt	0	1	0	1	12	4	0	18
	Calcarenite	2	3	8	3	26	19	0	61
	Total	2	4	8	4	38	23	0	79

B. Substrate x origin

Substrate	Native	Endemic	Naturalized	Total
Basalt	52	59	18	129
Calcarenite	11	0	61	72
Total	63	59	79	201

C. Origin x growth-forms

Origin	Tree	Small tree	Shrub	Twiner	Herb	Graminoid	Fern	Total
Native	1	0	6	2	13	21	20	63
Endemic	5	14	11	1	7	5	16	59
Naturalized	2	4	8	4	38	23	0	79
Total	8	18	25	7	58	49	36	201

D. Totals

	Restricted species	Total species	Area (ha)
Basalt	129	325	1188
Calcarenite	72	268	332

Notwithstanding the interaction between substrate and growth-form for native species (mainly due to herbs) that we considered above, there is a highly significant interaction between substrate and origin (Table 7). This is due to over-representation of natives and endemics on basalt and over-representation of naturalized species on calcarenite.

The last major comparison, origin x growth-form, is again highly significant (chi-squared statistic 149.45 with 12 d.f.).

TABLE 7

Summary of chi-squared tests of independence between substrate, origin and growth-form

	Chi-squared	D.F.	Significance
A. Substrate x Growth-form			
Total	34.9	6	**
Native	18.8	5	**
Endemic	—	—	—
Naturalized	5.0	5	ns
B. Substrate x Origin			
Totals	101.05	2	**
C. Origin x Growth-form			
Totals	149.45	12	**

Significance levels: ns $p > 0.05$; ** $p < 0.01$.

Plausible reasons for the significant results can be found in the geological age of the island and the history of settlement. Native and endemic species are over-represented on basalt which is at least 7 million years old. This allows considerable time for speciation and development of particular adaptations to the one substrate. On the other hand, the calcarenite is all late Pleistocene or younger and only a few tens of thousands of years old. This appears to be insufficient time for speciation of ''calcarenite endemics''.

Since settlement, large areas of lowland have been cleared, the majority on calcarenite. Much of this cleared area is grazed or cultivated, with large numbers of pasture grasses and weeds which are naturalized. The range of habitats is quite different for each substrate and therefore it is impossible to say whether it is the substrate or the habitat that is causing the observed differences.

In summary, these rather broad and crude data highlight many of the readily perceived differences between vegetation on both substrates. All of the comparisons considered above support the view that local differences occur between vegetation on calcarenite and basalt. Some differences operate on a broader scale than others but specific sampling would be necessary before one could confidently state that the differences are due solely to substrate.

Climate

Although the vegetation and the flora are in equilibrium with the present climate, occasional extremes cause severe local damage.

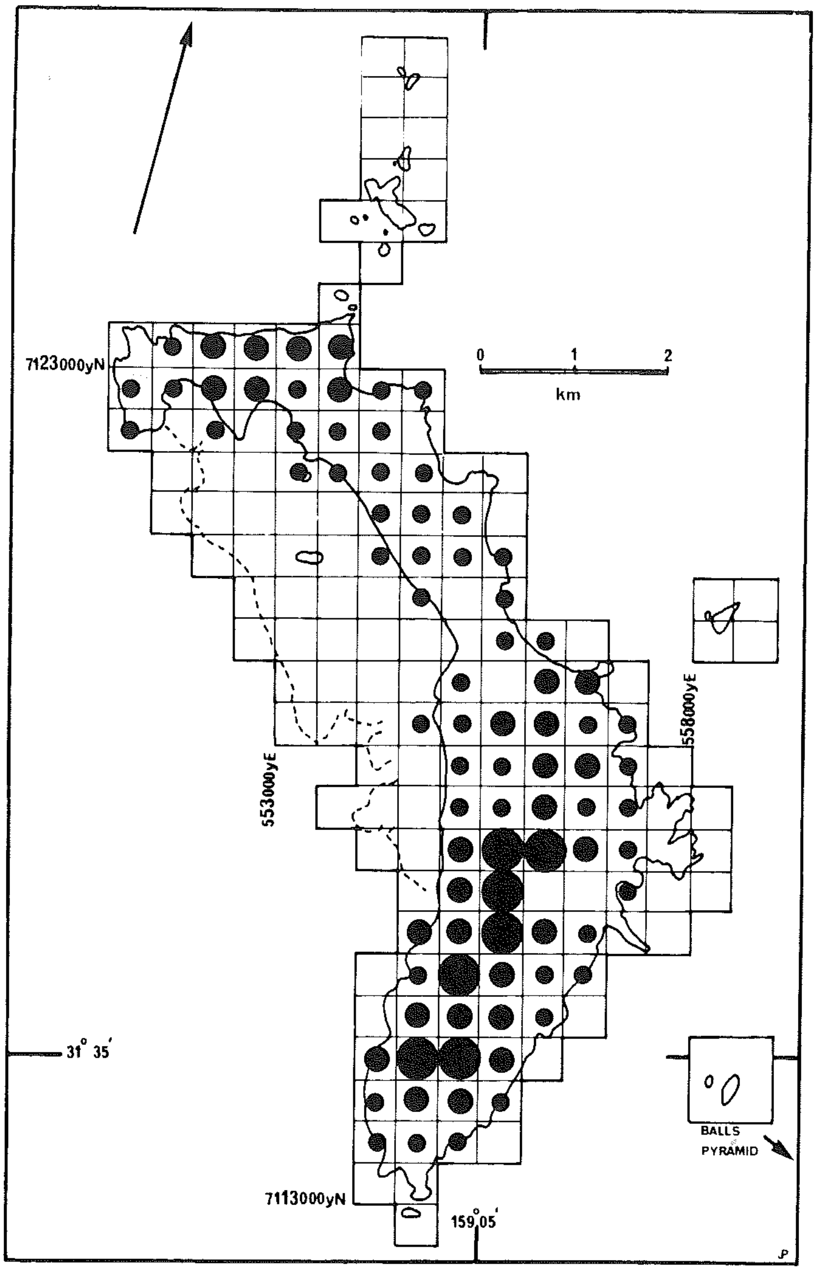

Figure 16. Number of vascular epiphytes recorded in 500 yard (457 m) grid squares. Nineteen species (13 ferns, 6 angiosperms) are regarded as epiphytes although some of the records may refer to occurrences on rocks, logs or soil.

Symbols: blank 0 or no records ● 1-5 species ● 6-10 species ● 10-14 species
Source: Pickard (Unpublished data).

Despite the high rainfall, water is probably a limiting factor in most summers when evaporation exceeds rainfall (Figure 8). This is severely exacerbated on sandy calcarenite soils by extended sequences of rain-free days in summer. In February 1977, after a period of many weeks with virtually no rain, leaves of many trees were showing stress symptoms: dying fronds of *Howea forsterana,* leaf fall on *Drypetes australasica,* and extreme desiccation of herbs in exposed sites. Most of these visible symptoms were reversed after a few light falls of 1–2 mm. However, as flowering in *Howea* *forsterana* takes four years from bud to seed, desiccation stress during a critical physiological phase could affect seed numbers up to four years later.

On an oceanic island it is impossible to separate the effect of wind from the effect of wind-borne salt spray. Exposure to constant wind causes a suite of effects in vegetation: stunted plants; contorted trunks; smooth, dense canopy; reduction in number of "mesic" plants and often, a reduction in leaf size (Boyce, 1954). These effects are well expressed along the coast and on ridges and crests on Lord Howe. For example, on the side of an exposed ridge near Transit Hill in *Drypetes australasica-Cryptocarya triplinervis* forest up to 12 m high, the canopy is smooth with less than 30 cm variation over areas up to one hectare.

The number of vascular epiphytes appears to be partially controlled by microclimate. Nineteen species of vascular epiphytes (13 ferns, 6 angiosperms) occur on the island and the largest numbers of species are found in the southern mountains (Figure 16). However, within this broad pattern, numbers of individuals are equally common in the humid *Bubbia-Dracophyllum* forest and stunted forests on windy exposed sites.

Although the wind resultants (Figure 11) indicate the direction and magnitude of onshore winds, streamlines in the vegetation provide the best integrated indicator of the actual wind direction experienced by the vegetation. The resultants do not correspond closely with canopy streamlines except close to the coast (Figure 11), where the streamlines radiate normally from the shore. Even here the pattern is disturbed by physiographic features acting as funnels or windbreaks, for example, in the bay immediately east of The Saddle, canopy streamlines indicate a northeast effective wind despite the southeast aspect, and at Dinner Run the streamlines show that southerly winds trapped behind Red Point are funnelled north up the creek (Figure 11).

Canopy streamlines in the hinterland are generally normal to ridge crests and fan up out of gullies, but this pattern is modified by topographic obstructions. Thus, immediately south of Mount Lidgbird the streamlines are arcuate, whereas in the bottom of The Saddle about 100 m lower, they are normal to the ridge.

An anomalous situation occurs in Erskine Valley where southeast onshore winds affect leeslope vegetation on a northwest aspect and the relatively weak onshore westerly winds gust violently out to sea to the east. In Erskine Valley on Scaly Bark Ridge (shown by star on Figure 11), the upper limbs of *Cleistocalyx fullagari* trees are bent downhill to the northwest which is in the opposite direction to what would be expected. Southeast winds flow up over The Saddle and down the ridges in Erskine Valley and the wind-sensitive *Cleistocalyx* trees assume the anomalous downhill bending. Fitzgerald (in Hill, 1870) provides an entertaining description of a storm in Erskine Valley: "The water on the saddle [sic] on which Ned [Edward King] counted has been destroyed by pigs, so they descend a little into Erskine Valley . . . in search of water . . . The wind began to whistle up the valley, then came a peal of thunder and the large drops pattered. Then peal on peal, and flash on flash, and the wind grew into a furious gale that cut through to the very marrow in the bones . . . at the narrow end of a tunnel through which wind and rain rushed furiously . . . ."

This rather coloured description of a storm provides testimony of the lee slope winds. Evidence of the concentration of the weak westerlies is provided by an inscription southeast from The Saddle on the nautical chart of the island*, which warns: "Ships approaching this 'Mountain aspect' nearer than 1½ miles will risk (with off-shore winds) dismasting by the gusts which alternate with dead lulls". While

*The original chart was drawn in 1853 by Captain H.M. Denham R.N. and published in 1863 as "South west Pacific, Lord Howe Island and Ball's Pyramid-Lord Howe Island and adjacent islets and reefs" by the Admiralty. Current editions still bear the caution.

Figure 17. Salt spray blowing off the coral reef during a strong southwesterly wind. Mount Eliza in the rear, Rabbit Island on the right.

there is other evidence that Fitzgerald tended to exaggerate, the quality of the chart prepared by Denham gives little indication that he was anything but a meticulous and accurate cartographer. His inscription shows that winds gust up Erskine Valley, over The Saddle and out to sea with unfortunate consequences to unwary mariners.

Strong winds and cyclones are not unknown on Lord Howe (p.148) but are of such short duration that they have little effect on, for example, streamlines. Severe damage to vegetation during cyclones is rare and, even then, very localized. At the most, some trees are blown over or fall over when the rain-soaked soil slumps.

Salt spray carried by the wind reaches virtually all parts of the island. As early as 1853 Macdonald observed that wind "often proves destructive to vegetation, by blowing the finely-divided spray from the reef over the unprotected parts. From May to September it is most severe, and its blighting influence is frequently observed within a few hours, bananas, potatoes, and many other plants become quite black and shrivelled up." Oliver (1917) in describing the valley between Old Gulch and Mount Eliza says that "on windy days the whole valley is drenched with salt spray." Salt drops are carried to at least 70 m elevation on Dawson Point Ridge during moderate storms (Figure 17, field observation 13.v.1971). It is difficult to estimate how high salt is blown but indirect evidence suggests that it reaches the top of the mountains. Several species of sea-birds (Masked Booby, *Sula dactylatra;* Red-tailed Tropic Bird, *Phaethon rubricauda;* and Providence Petrel, *Pterodroma solandri*) soar from sea-level to heights in excess of 1000 m on updraughts up the faces of cliffs. Foliar analyses for sodium of *Randia stipulosa, Bubbia howeana* and *Pittosporum erioloma* from 25, 200 and 840 m show no decline with altitude (Pickard, 1978).

The rate of deposition depends largely on wind and sea swells, and after storms even plants believed to be salt tolerant may show leaf death, for example, foredune colonizers such as *Vigna marina, Ipomoea brasiliensis* and the naturalized *Hydrocotyle bonariensis.* Some trees, for example, *Howea forsterana* and *Lagunaria patersonia* also have salt-scorched leaves after gales. Salt spray is a major factor in the formation of "secondary canopies" discussed below (p.249).

Along most of the coast of Lord Howe there is little evidence of the "salt spray community" of Boyce (1954), except within a few metres of high-tide mark. Immediately behind this strip the dominant forests start. *Howea forsterana* forest provides a good example: it grows from sea-level to at least 360 m on a variety of substrates. At Little Island and Far Flats (pp.000, respectively) the forest is immediately above a narrow band of sedges and twiners. The presence of storm-washed flotsam inside the edge of forest at Far Flats shows how exposed the community is here. Both these stands are about 5–10 m high, but a much lower stand occurs in the lee of the sand dune at Blinky Beach (Figure 44). The palms here showed extensive leaf death after a storm in 1972.

The *Drypetes australasica-Cryptocarya triplinervis* association behaves in a similar manner, except that near the more exposed sections of the coast it is replaced by the exposed facies of the association. The two Narrow Sclerophyll Scrub communities are probably the nearest thing to a 'salt spray community' on the island. Both *Melaleuca howeana* and *Cassinia tenuifolia* associations are virtually restricted to exposed cliffed headlands along the coast (see vegetation map). These stands show most of the features described earlier.

The Gnarled Mossy Forest on Mounts Lidgbird and Gower is evidence of the very regular and persistent cloud on the mountains. Inside the cloud, evaporation and transpiration are reduced and humidity is increased. Effective precipitation inside the cloud is higher than outside and much of this increase comes from direct interception of cloud water by vegetation. However, this microclimate is subject to rapid change. Within the space of 30 minutes in February 1976 conditions on Mount Gower changed from dripping cloud to sunny and dry. At the same time, epiphytic filmy ferns and macrolichens changed from soggy to dry and brittle.

The razorback summit of Mount Lidgbird has less cloud than the summit plateau of Mount Gower and the vegetation reflects this. There are fewer species and individuals of non-vascular epiphytes, and the *Bubbia-Dracophyllum* Gnarled Mossy Forest is less well developed.

Sea-birds

Subfossil bones of sea-birds indicate that large numbers of birds have nested on the island for a long time (van Tets & Fullagar, 1974). Short-term and local effects are visible. The estimated one million pairs of nesting birds (Table 8) influence the development of vegetation on two levels: at the individual plant level and at the community level. I will consider four bird species which affect individual plants, then birds which affect weed distribution and finally the role of another species in the forests.

Noddies (*Anous stolidus*) roost, among other places, in shrubs of *Melaleuca howeana, Lagunaria patersonia* and *Celtis amblyphylla* (Figures 18 and 19). This kills or causes a general die-back in *Melaleuca,* but the broad-leaved *Lagunaria* and *Celtis* appear unaffected. Masked Boobies (*Sula dactylatra*) nest on the ground between tussocks of *Poa poiformis* and *Cyperus lucidus* (Figure 20) and kill one or two adjoining tussocks by mechanical damage and/or excess faecal nutrients. Wedge-tailed Shearwaters (*Puffinus pacificus*) nest in shallow burrows wherever there is sufficient soil on the off-shore islets. More often, because the soil is too shallow, the nest is merely a cave excavated under a tussock of *Poa poiformis* or *Cyperus lucidus* (Figures 20 and 21). Death of these tussocks is frequent in dry summers when the little soil present dries out. On the summits of Mounts Lidgbird and Gower, there are sometimes dead mosses and lichens around the entrances to the burrows of Providence Petrels (*Pterodroma solandri*). During nesting, the petrels contribute to mass-movement of the usually wet soil but there is no indication that the vegetation is not able to tolerate the movement. Many stems are curved at the base apparently compensating for

Figure 18. Large amount of twig death on *Melaleuca howeana* caused by nesting noddies (*Anous stolidus*) on Roach Island. Compare with *Lagunaria* in Figure 19. Burrow of Wedge-tailed Shearwater (*Puffinus pacificus*) in left foreground partially obscured by herbs.

Figure 19. Noddies (*Anous stolidus*) nesting on *Lagunaria patersonia* sheltered by a basalt dyke on Roach Island cause virtually no twig death. Compare with *Melaleuca* in Figure 18.

TABLE 8

Summary of numbers and distribution of seabirds†

Species	Number of breeding pairs	Breeding season	Main distribution	Nest	Vegetation*
Sooty Tern *Sterna fuscata*	100 000–1 000 000	Sept-Jan	Offshore islands, Malabar cliffs	Surface	IcCg, Cl, Pp, Cliff
Wedge-tailed Shearwater *Puffinus pacificus*	28 500	Nov-Mar	Offshore islands, Phillip Bluff-Phillip Point	Short burrows	IcCg, Cl, Pp, Cliff
Providence Petrel** *Pterodroma solandri*	>20 000	May-Oct	Mts Lidgbird and Gower alt. >535 m.	Long burrow	Cg, Hc, BhDf, BcMep
Fleshy-footed Shearwater** *Puffinus carneipes*	17 500	Nov-Mar	Calcarenite area Neds Beach-Valley of Shadows	Long burrow	DaCt, Hf
Masked Booby *Sula dactylatra*	300	Sept-Apr	Roach & Mutton Bird Islands, Mutton Bird Point	Surface	IcCg, Cl, Pp

† Source: Fullagar *et al.* (1974), and field observations.
* Vegetation abbreviation: See Table 4.
** These estimates have been confirmed by detailed counts (P. Fullagar, pers. comm. 1981).

downslope creep of the soil. In each of the above examples the effects are localized and restricted to individual plants.

One consequence of both the high nutrient levels and mechanical disturbance in the nesting areas is the enhancement of the weed distribution. For example, there are many exotic weeds in openings in the *Boehmeria-Macropiper* scrub and *Hedyscepe* palm forest on the terrace, and *Bubbia-Dracophyllum* forest on the summit of Mount

Figure 20. Burrows of Wedge-tailed Shearwaters (*Puffinus pacificus*) under tussocks of *Poa poiformis* on Roach Island.

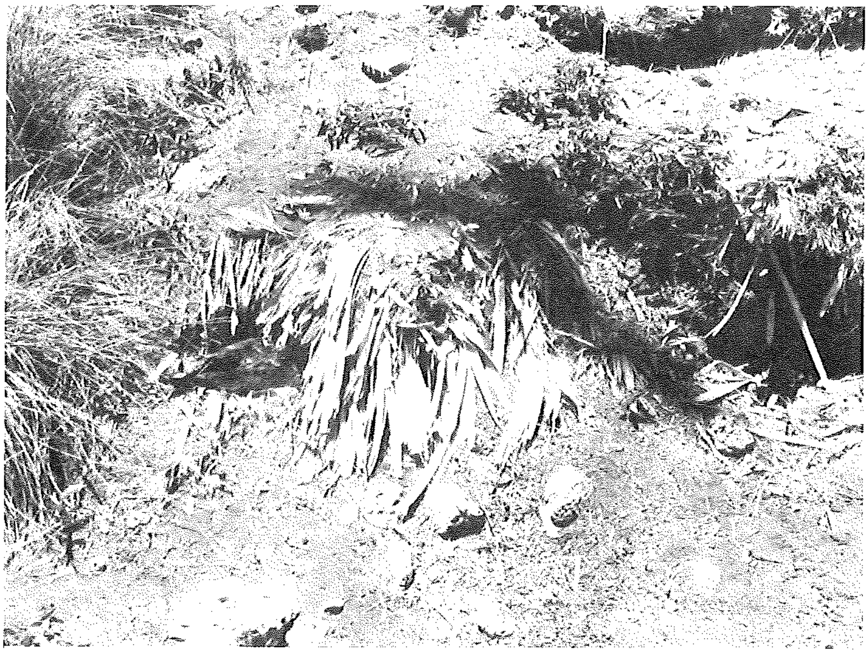

Figure 21. Tussock of *Cyperus lucidus* killed by burrowing Wedge-tailed Shearwaters (*Puffinus pacificus*) on Mutton Bird Island.

Lidgbird. These areas are inaccessible to feral animals and have few human visitors, so the only likely dispersal mechanisms are wind and/or birds. In either event, adventive species such as *Bidens pilosa, Bromus unioloides, Cerastium glomeratum, Gnaphalium spicatum, Hypochaeris radicata, Lilium formosanum, Poa annua, Rumex brownii, Solanum nodifolium, Sonchus oleraceus* and *Verbena bonariensis* are scattered over the nesting areas.

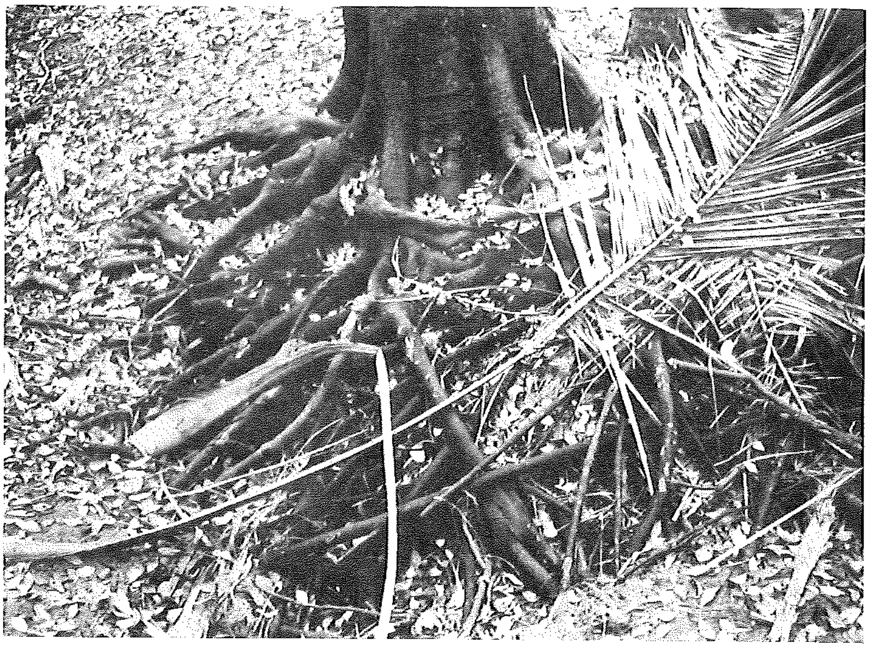

Figure 22. Network of surface roots of *Drypetes australasica* exposed after collapse of burrows of Fleshy-footed Shearwaters (*Puffinus carneipes*) in *Howea forsterana* forest. On the Big Mutton Bird Ground above Stevens Point.

Figure 23. Young plants of *Howea forsterana* in a *H. forsterana* forest with many burrows of Fleshy-footed Shearwaters (*Puffinus carneipes*). No seedlings are visible. On the Big Mutton Bird Ground above Stevens Point.

On the off-shore islands, which are also inaccessible and infrequently visited, a more restricted but similar weed flora is developed on nesting areas: *Anagallis arvensis, Chenopodium murale, Oxalis corniculata, Polycarpon tetraphyllum, Solanum nodifolium, Sonchus oleraceus* and *Digitaria sanguinalis*.

Fleshy-footed Shearwaters (*Puffinus carneipes*) nest in *Howea forsterana* and *Drypetes-Cryptocarya* forests on calcarenite in the Big Mutton Bird Ground which runs from Neds Beach to Valley of the Shadows. The shearwaters nest in burrows up to 1.5 m long and 1 m deep in the sandy soil below a network of shallow roots which reinforce the burrow roofs. When burrows are disused between breeding seasons or when the soil dries out in droughts, the roofs often collapse leaving trenches crossed by a network of exposed roots (Figure 22). Conversely, the roots of some trees are covered with soil excavated from burrows. Some island residents assert that these conditions kill canopy plants and prevent regeneration in both *Howea forsterana* and *Drypetes-Cryptocarya* forests. The area is an ideal site to examine the vegetation/bird equilibrium and seek evidence of bird damage to the forests.

In the *Drypetes-Cryptocarya* forest between Neds Beach and Jims Point there are virtually no seedlings of the two dominants and there is no other understorey present. Further south above Middle Beach there is a sparse understorey of young canopy plants. Canopy cover in these forests (80–100%) is similar to other *Drypetes-Cryptocarya* stands with more abundant seedlings and denser understoreys but no nesting birds. *Howea forsterana* forest here is uneven-aged with many seedlings and young plants (Figure 23) but these are fewer than occur in other stands without birds.

These observations partially support the assertion that the birds damage the forests. However, I believe a more realistic view is to consider that the nesting birds reduce the density of young plants but not to levels that prevent maintenance of the present communities.

Introduced animals

Five of the exotic animals now on Lord Howe affect the vegetation (Table 9). Four, goats, pigs, rats and man, are notorious for their ability to alter and damage vegetation on oceanic islands. Cattle do not enjoy the same unenviable reputation, but on Lord Howe cattle are second only to man for the damage they cause. As the effects of cattle are a consequence of management decisions by man, I will discuss both in the next section.

The following discussion of goats is a brief summary of earlier studies (Pickard, 1976). Goats were introduced as domestic livestock before 1850 and were running wild by 1851. Until the extermination programme started in 1970-1971, goats roamed the northern hills and southern mountains (Figure 42) but preferred the low forest and scrub of exposed sites (Figure 24). Generally, the only evidence of goats was the existence of small bare patches near their camps and a typical flora of nitrophilous weeds. By 1981, the goat population had been reduced (especially in the northern hills) but not eliminated.

TABLE 9

Exotic mammals which affect the vegetation†

Species	Distribution	Vegetation*	Activity
Goat *Capra hircus*	Northern hills, southern mountains, Little Slope (now eliminated), Rabbit Island. (Never on summit of Mount Lidgbird, or other offshore islands).	Cliffs, exposed areas. DaCt, DaCtx, Hf, BhDf, Ca, Mh, DfMn, MFH, Pp.	Browsing, camping in caves, faecal downwash from camps.
Pig *Sus scrofa*	South of Intermediate Hill, particularly Fern Patches and Erskine Valley; Big Slope (Never on offshore islands).	Forested areas. DaCt, Cf, Cq, LM, Cg, Hb, Pf, BhDf(?), DfMn.	Rooting for rhizomes eating seeds.
Rat *Rattus rattus*	Entire island (Never on offshore islands).	All types, especially BhDf, Hc, Hf.	Eating seeds, fruit, rhachis.
Ox *Bos taurus*	Cleared lowlands and adjacent areas.	Cleared and disturbed forest.	Browsing, grazing, spread of weeds, prevention of regeneration.
Man *Homo sapiens*	Northern hills, cleared lowlands and adjacent areas, tracks through bush. Rarely in areas with difficult access.	All types where readily accessible.	General destruction for building, grazing, etc., accidental spreading of weeds, trampling.

* Vegetation abbreviations: See Table 4.
† Source: Pickard (1976, unpublished data and field observations).

As early as 1869 goats were blamed for damaging the vegetation but little evidence was available. By comparing Oliver's (1917) description of Little Slope with the present vegetation, I have shown how goats destroyed a large stand of *Cyperus lucidus* Tall Grass and removed all small plants of *Howea forsterana* (Pickard 1976, unpublished data). Using Oliver's description of vegetation between North Beach and New Gulch, it is possible to refute an assertion by several island residents that the *absence* of goats following the extermination programme has caused changes. The residents assert that the goats maintained the vegetation in an essentially grass- and sedge-free state, and that when goats were eliminated the vegetation was invaded by *Phragmites australis, Poa poiformis* and *Cyperus lucidus* to form the present cover.

Oliver describes the vegetation between North Beach and New Gulch as: ". . . an open-scrub association mixes with the herbaceous plant formations. In the most

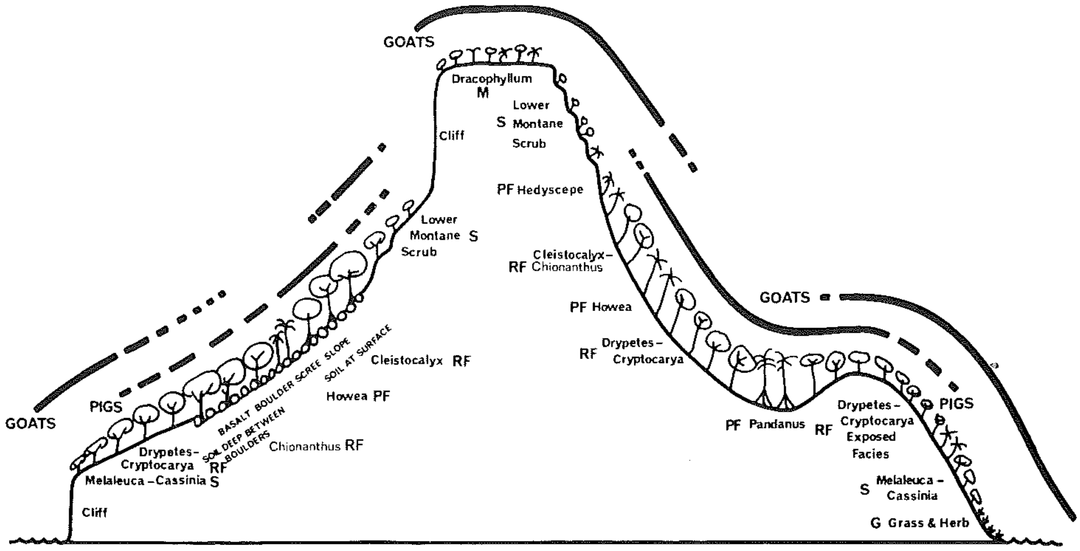

Figure 24. Diagrammatic cross-section of the southern mountains showing habitat preferences of goats and pigs. Goats prefer low forest and scrub on exposed sites, pigs the denser and taller forests on sheltered sites. Goats also browse on the summit of Mount Gower in the dense *Bubbia-Dracophyllum* forest (from Pickard 1976).
Abbreviations: RF Rain forest
PF Megaphyllous broad sclerophyll forest (palm and pandan)
M Montane forest and scrub
S Scrub
G Short grass and broad-leaved herb vegetation

exposed portions there occur large rounded bushes of *Melaleuca ericifolia* [*M. howeana*], 6 m. to 8 m. across and ½ m. to 1½ m. high, closely fitting the ground all round, and highest in the centre [Figure 25]. Other shrubs scattered here and there in the meadow formation are *Cassinia tenuifolia, Myoporum insulare* and *Coprosma prisca*.

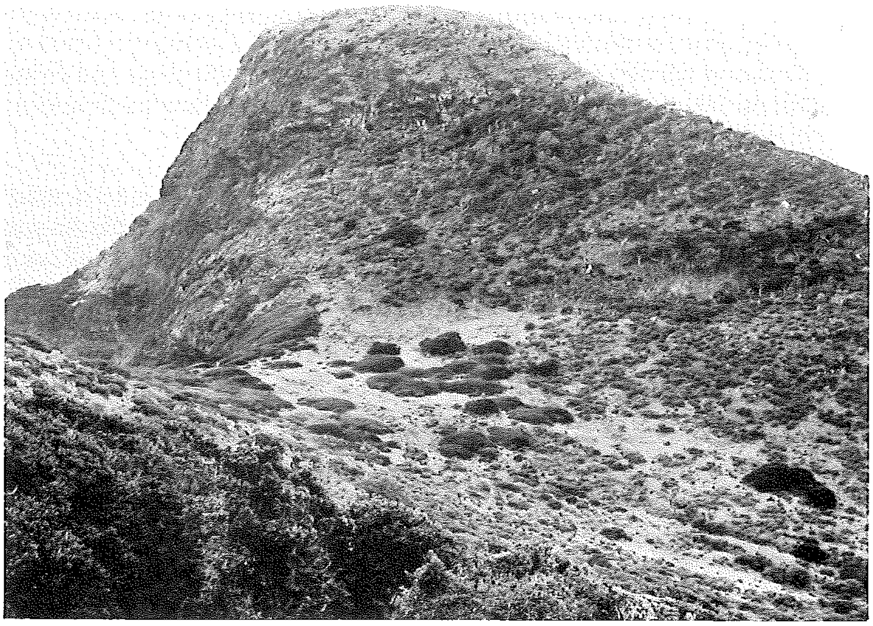

Figure 25. Mount Eliza and the gap above New Gulch from the west. Domes of *Melaleuca howeana* occupy the lowest section of the gap. Further right (towards North Beach and Figure 26) are sparse shrubs of *Cassinia tenuifolia,* mixed with *Poa poiformis, Cyperus lucidus, Phragmites australis* and *Scirpus nodosus.* The mid slopes of Mount Eliza support *Drypetes australasica-Cryptocarya triplinervis* exposed facies which merges into the low scrub and grass on the upper slopes.

Figure 26. A small black goat (lower right foreground) in *Poa poiformis* and *Scirpus nodosus* Short Grass north of *Howea forsterana* forest between North Beach and New Gulch. Scattered shrubs of *Cassinia tenuifolia* and *Myoporum insulare* occur left of the goat. Oliver's (1917) description of this area reveals that the vegetation has not changed since 1913.

"In the gap between Mount Eliza and North Head the wind continually sweeps through, usually with great violence. Here there are no trees and only a few detached shrubs, but the area is occupied by formations of herbaceous plants. In the most exposed portion are low succulent plants . . . *Mesembryanthemum aequilaterale* [Carpobrotus glaucescens] and *Lobelia anceps* . . .". This ". . . is replaced on the leeward side by a covering, 1 m or more tall, of rushes and grasses, with a few shrubs intermixed . . . *Scirpus nodosus* is the dominant plant. Each side up the hillslope it mixes with *Cassinia* scrub, which then passes to forest. Among the *Scirpus* there grow *Poa caespitosa* [*P. poiformis*], *Cynodon dactylon, Lobelia anceps* and the trailing plant *Ipomoea palmata* [*I. cairica*].

"Over extensive areas the tall grass *Phragmites communis* [*P. australis*] is mixed with *Scirpus nodosus* and the shrub *Cassinia tenuifolia.* The whole association is very dense and up to 2 m. in height. Trailing over it are *Ipomoea palmata* [*I. cairica*] and *Stephania Forsteri* [*S. japonica*]. In the lowest portion of this formation near the forest large shrubs, 3 m. tall of *Coprosma prisca* and *Myoporum insulare* are fairly common."

This description applies perfectly to the vegetation in the area in 1970 when goats still grazed and browsed (Figure 26). I have been unable to detect any appreciable change since the virtual elimination of goats, but I lack quantitative data. There is no evidence to support the islanders' claim.

Although many visitors have commented in passing on the effects of pigs, no detailed studies have been made. The following discussion is summarized from Pickard (1978). Pigs were present on the island in 1839 as domestic stock, and were feral by 1851. They are still present but are restricted to the southern mountains south of Intermediate Hill (Figure 42). They have preferred habitats, dense forest, which overlap slightly with those of goats (Figure 24). Despite a concerted extermination programme from 1977 to 1981 a few pigs still remained in 1981.

By 1869 the vegetation was apparently showing the effects of 20 years grazing by pigs and goats. However, it is impossible to separate pig and goat effects except in certain areas, for example, Little Slope, where there have been no pigs for 50 years. The main effects of pigs seem to be rooting-up areas in search of roots and rhizomes. This leaves a churned-up soil surface, which together with nutrients from faeces makes an ideal seed-bed for weeds. As most pig activity is restricted to dense forests where light levels are low, weed invasion is low. By 1981, following virtual elimination of the pigs, there was much less direct evidence of rooted-up areas.

Rats are the most recent invader of the island; they did not arrive until 1918, 76 years after settlement. Today, only the off-shore islets are rat-free (Figure 42). Rats cause considerable loss of palm seed which seriously reduces income to the island. Despite this, no studies have been made. Their main effect is seed predation on a range of plants, for example, *Howea* spp., *Hedyscepe, Lepidorrhachis* and *Chionanthus.* They also eat flowers of *Dietes,* and the rhachis of *Hedyscepe* and *Cyathea howeana.* On Little Slope a large rat population, combined with goats, has prevented regeneration of *Howea* forest for almost 50 years.

Although the Lord Howe Island Board has poisoned rats for many years, the effect is negligible away from the settled areas. Until 1980 the programme was a failure because it was not based on information on distribution, behaviour or feeding preferences of the rats. In 1980 a new blanket-poisoning programme commenced in many areas. This has reduced rat numbers considerably.

The effects of all the feral mammals are poorly known and understood. Since 1977 data on pig stomach contents, rat density and habitat preference have been accumulated (B. Miller, pers. comm.) but have not been analysed. This information should define the nature of the problem caused by the feral animals and suggest worthwhile avenues and methods of control and extermination.

Settlement

Lord Howe Island was free of *Homo sapiens* until it was sighted in 1788 and subsequently settled in 1833. The early settlers cleared vegetation to survive: they needed gardens and pastures. Once the settlement was established, the needs changed: to vegetable export in the 1850's, to palm seeding in the 1890's and to tourism in the 1930's. Each phase continued the disturbance and expanded the cleared area.

In gross terms the 150-odd years of settlement have had little effect on the vegetation: less than 20 per cent of the vegetation is disturbed and less than 10 per cent is cleared. However, these gross percentages conceal severe local damage, and both past and continuing disturbance for both economic and other motives. I will discuss effects of clearing for gardens and pastures, palm seeding, construction, and finally some consequences of tourism and attempts at aesthetic improvement.

Old Field Succession

In the past, many islanders practised shifting cultivation. An islander chose a piece of forest, cleared it, planted vegetables or fruit trees and cultivated it for a few years before abandoning it. Frequently another islander would take over the management, often with a different crop. After abandoning it, the islander may seek out another new site and repeat the process. Consequently the central section of the island is dotted with small abandoned gardens, which are sites of old field succession and foci for weed invasion.

Abandoned gardens were first described by Moore (1869) "[Abandoned gardens and] clearances of the flats are now almost wholly occupied by two grasses which are common about Sydney, *Cynodon dactylon* and *Sporobolus elongatus*

Figure 27. Dome-shaped shrubs of *Cassinia tenuifolia* and *Ageratina adenophora* (erect herb between *Cassinia*) invading pasture of native grasses and sedges in Portion 130 (see Figure 28).

[S. africanus]".". . . *Verbena bonariensis, Ricinus communis, Solanum lacinatum* [*S. aviculare*], *Sonchus oleraceus,* and other smaller kinds, evidently foreigners to the soil, had, from neglect, taken almost entire possession of fine tracts of cleared ground, and had become in other parts very troublesome weeds." *Solanum aviculare,* which I consider native rather than introduced, is now rare on abandoned clearings at low altitudes. *Ricinus communis* has a chequered history (Pickard, unpublished data) on the island; sometimes abundant, sometimes rare. From 1970 to 1981 it was uncommon on old clearings. It is virtually impossible to document the chronology of owners, management, and crops of the various gardens. I will discuss several examples for which I have good information, as they illustrate the general principles. The discussion is based largely on old maps (particularly Ferrier's 1923 map; Pickard, unpublished data), field observations and discussions with elderly residents of the island.

The consequences of clearing are best considered on a scale of increasing complexity, outlined here and discussed in detail over the next few pages. The simplest clearing is a small opening in the forest which is immediately abandoned (e.g. portion 54). Next is an abandoned pasture being invaded by native species (e.g. portion 130) or exotic shrubs (e.g. Retmocks Garden, Valley Garden). More complex again is the onset of a steady state when neither pasture nor forest advance (e.g. Fred Nichols Garden). Next is the steady state relying on the presence of grazing cattle and fences (e.g. Stevens Point). Finally there is the interaction of clearing, grazing and wind (e.g. above Middle Beach). All these examples and some others are considered in more detail below.

Portion 54 is a tongue of *Drypetes-Cryptocarya* forest on basalt protruding into the *Howea forsterana* forest behind Neds Beach. In 1923 Ferrier described this area as "overgrown and dense palm". At some time in the 1950's it was cleared by a resident for a house which was never built and the clearing was abandoned. The clearing is now well covered by dense regrowth of the various trees from the surrounding forest: *Cryptocarya, Drypetes, Celtis.* The soil surface is covered with a mat of *Vinca major,* an introduced herb, which is restricted to this immediate vicinity. A similar example occurred along an electricity power line which until 1980

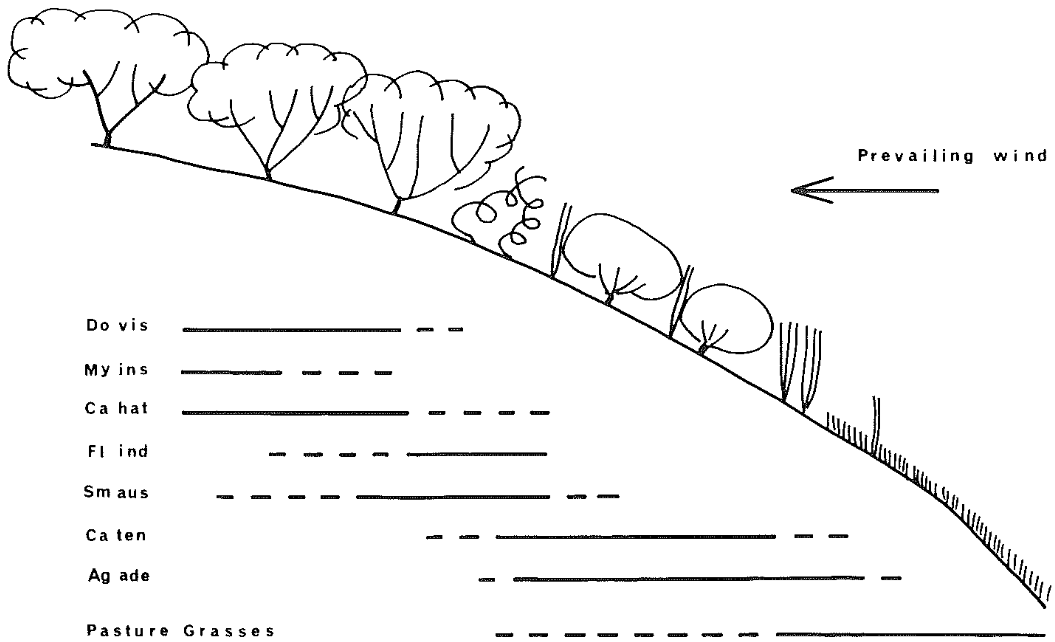

Figure 28. Diagrammatic cross-section of pastures in Portion 130 being invaded by shrubs (see Figure 27). Horizontal lines indicate range of occurrence of the following species:

Do vis	*Dodonaea viscosa*	Sm aus	*Smilax australis*
My ins	*Myoporum insulare*	Ca ten	*Cassinia tenuifolia*
Ca hat	*Carex hattoriana*	Ag ade	*Ageratina adenophora*
Fl ind	*Flagellaria indica*		

ran over Windy Ridge through *Drypetes-Cryptocarya* forest about 5 m high. A narrow strip of vegetation was cleared along the power line to stop branches hitting the wires. Continual cutting was required to minimise regrowth along the strip and arrest the succession. The response of the vegetation was a dense tangle of the vines *Flagellaria indica* and *Smilax australis*. Similar vine tangles are common elsewhere on Lord Howe in natural light-breaks or under sparse canopies.

Portion 130 runs from swampy flats beside Soldier Creek up onto a steep north-facing basalt slope which is exposed to winds. The original cover on the slope, *Dodonaea viscosa* scrub, has been substantially cleared for a pasture of stoloniferous grasses and herbs (Figure 27). As the 1923 map shows the clearing, the paddock is at least 50 years old. *Dodonaea* is colonizing the eastern edge of the paddock (Figures 27 and 28). *Cassinia* and *Ageratina* are also invading and are very dense at the edge, but neither penetrates far into the *Dodonaea*. A tangle of the vines *Flagellaria* and *Smilax* occurs between bushes of *Cassinia*. The western side of the paddock is in a gully and abuts *Drypetes-Cryptocarya* rainforest. Here it is more sheltered and consequently *Cassinia* does not mark the edge. Instead there are various young trees from the forest: *Dysoxylon, Polyscias, Howea forsterana* and *Guioa*. *Cassinia* is invading several other exposed abandoned clearings: The Rib, above Mosely Park, and on a site cleared for airstrip fill near Salmon Beach. On Peach Tree Ridge below Intermediate Hill, a comparable pattern occurs but with *Myoporum insulare* instead of *Cassinia*. The Red Ground is being invaded by both *Cassinia* and *Myoporum*. In all these clearings, pasture is being invaded when cattle grazing is either reduced or stopped.

Retmocks Garden on the northern side of Windy Ridge has a chequered history. A resident cleared some *Drypetes-Cryptocarya* forest for a fruit garden. At about the same time, a second garden was cleared next to, but separated from the first by a thin strip of trees. Onions were grown in this second garden. When Retmock took over both gardens he removed these trees and used the whole garden for fruit until abandoning it about 1940. Today it is a series of dense thickets of Cherry Guava (*Psidium cattleianum*) and Guava *(P. guajava)* (Figure 29). A few peaches (*Prunus*

Figure 29. Cherry Guava (*Psidium cattleianum*) invading Retmocks Garden.

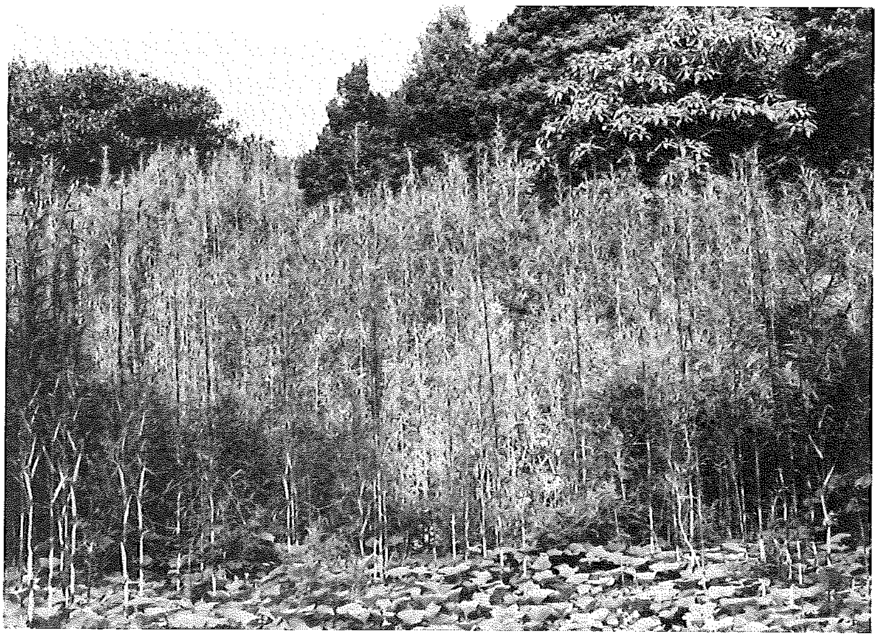

Figure 30. Bamboo (*Phyllostachys aureus*) invading Valley Garden. Cultivated cucurbits in the foreground.

persica) and Rough Lemon (*Citrus limonia*) remain from the original planting. Rough Lemons were used as root-stocks for oranges and mandarins and have probably taken over from them when the trees were neglected. *Paspalum* and *Pennisetum* form a dense ground cover with various introduced herbs: *Bidens, Verbena* and *Gnaphalium* spp. The garden is a good example of many gardens elsewhere on the island that are neglected or poorly managed, for example, Banyan Garden.

A comparable situation involving different species occurs in Valley Garden. This is in a solution doline on the junction between the basalt and calcarenite. As it is

Figure 31. Grazing paddock of *Pennisetum clandestinum* near Jims Point showing the lack of regeneration of forest caused by cattle grazing and intense competition by *Pennisetum*. Nesting Fleshy-footed Shearwaters (*Puffinus carneipes*) cause the hummocky microrelief. The paddock is within the Big Mutton Bird Ground.

very sheltered and the soil is enriched from the basalt slopes it is an ideal site for a garden. The original vegetation on calcarenite was *Howea forsterana* with many *Ficus* and *Celtis*. The ground cover would have been variable because of nesting Fleshy-footed Shearwaters (*Puffinus carneipes*). The basalt slopes on the south are steeper and support dense forest of *Drypetes-Cryptocarya*. W. Whiting apparently cleared the basin some time after 1912 to plant oranges. Before abandoning it in 1939 he planted the bamboo *Phyllostachys aureus* on the eastern side. From 1939 to 1981 various residents have used the garden and now bananas, pumpkins and other vegetables are grown there with some of the orange trees planted by Whiting. However, by 1981, *Phyllostachys* had spread vegetatively across the garden, to cover more than three quarters of the original clearing (Figure 30). It had not yet spread into the adjoining forests. It is dominating other weeds such as *Duchesnea, Solanum mauritianum,* and *Tropaeolum*. Thin vines such as *Stephania* and *Parsonsia* form a tangle about 1 m deep over the whole basin.

A steady state between forest and grass exists at Fred Nichols Garden behind North Beach. In 1840 Captain Middleton settled at the foot of Mount Eliza and Foulis' 1851 map (Foulis, 1853) shows a clearing there. Subsequently in 1898 and 1923 it was marked on maps as a garden. Today the garden remains as a 50 m square patch of Rhodes Grass (*Chloris gayana*) in the *Howea forsterana* forest. The dense *Chloris* up to 0.75 m tall effectively stops palm regeneration, and shade in the dense *Howea* forest stops the *Chloris* spreading.

Above Stevens Point is an excellent example of a steady state maintained by cattle and a fence. The area, which is part of the Big Mutton Bird Ground described above, was originally *Howea forsterana* forest on calcarenite soil. Fleshy-footed Shearwaters nest throughout the area on both sides of the fence (Figures 23 and 31). Cattle eat any Howeas within reach through the fence (Figure 32) and kill any seedlings which germinate in the *Pennisetum clandestinum* pasture (Pickard, unpublished data). *Pennisetum* has invaded the palm forest for a short distance, presumably stopping when light becomes limiting.

Figure 32. *Howea forsterana* eaten by cattle leaning over the fence (right, strung between tree-trunks). In the grazing paddock (upper right) there are no young *Howea*. Paddock near Salmon Beach.

This and other steady states are maintained by the combination of cattle and fence; they can be altered by any of a number of changes. The simplest is to remove the fence and allow the cattle to graze unhindered. Fences are rarely removed on the island to allow cattle free grazing but poor maintenance and broken fences lead to the same result. The cattle kill young plants and the pasture spreads (Figure 33). Alternatively, the cattle could be removed, but the resultant changes are not so simple to predict. Where the grazed area is surrounded by ungrazed forest or if a large number of the original trees remain, regeneration of the vegetation may be rapid (Figures 34 and 35). However, if the area is very close to other grazing paddocks with

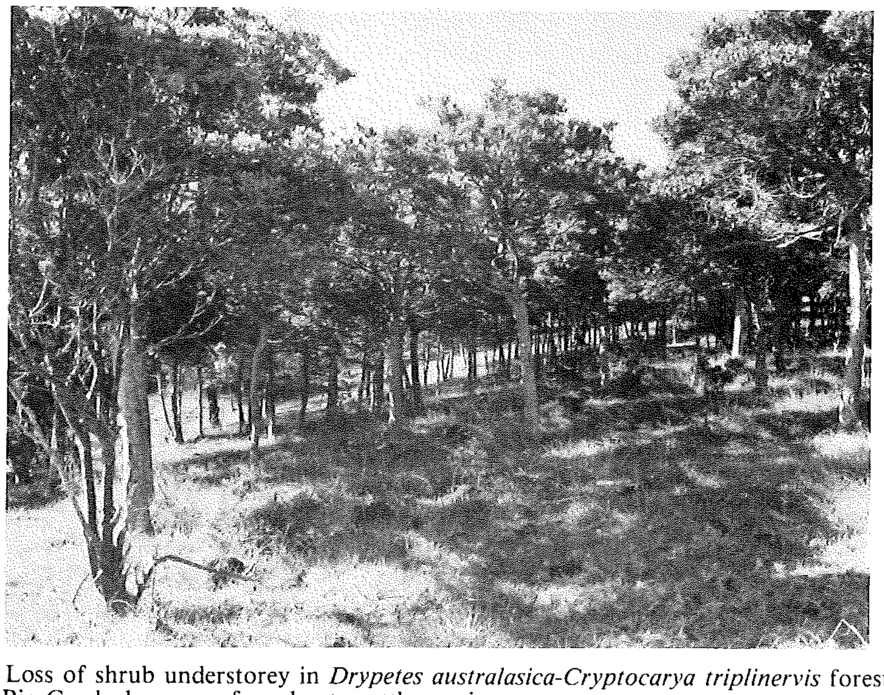

Figure 33. Loss of shrub understorey in *Drypetes australasica-Cryptocarya triplinervis* forest near Soldier or Big Creek, because of moderate cattle grazing.

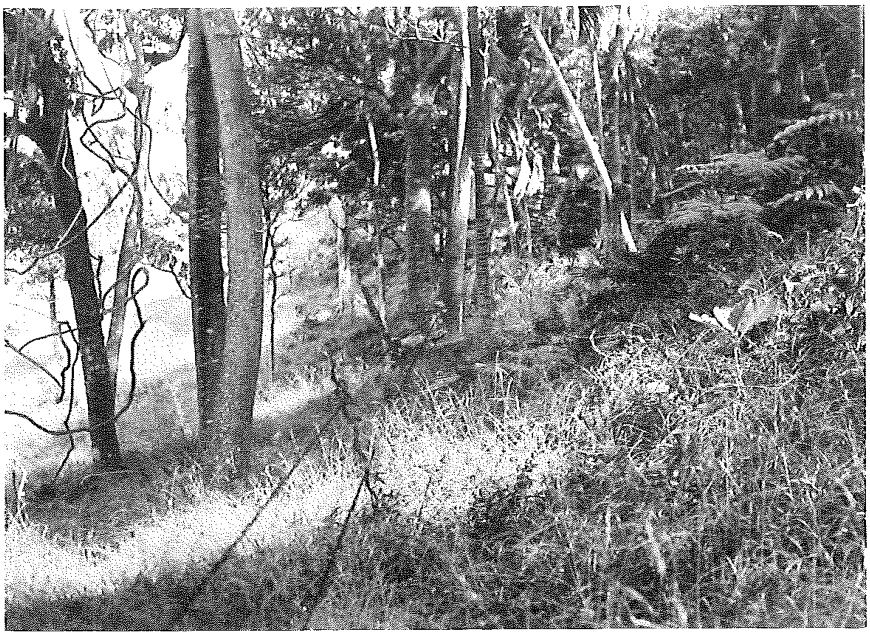

Figure 34. Regeneration of grazed forest can be rapid if sufficient seed sources remain and the forest is not invaded by *Pennisetum* or *Stenotaphrum*. Ten years after fencing to exclude cattle this *Drypetes australasica-Cryptocarya triplinervis* forest on the ridge north of Soldier or Big Creek has a well-developed understorey of shrubs, ferns and herbs.

Pennisetum or *Stenotaphrum* then regeneration is very slow. *Pennisetum* is a fast-growing grass which, if ungrazed, quickly forms dense swards up to 1 m deep (Figure 47). Under these conditions, germination and establishment by any other plant is markedly reduced. Even species with large seeds, such as *Howea* and *Drypetes,* almost invariably fail. Consequently, the present pasture/forest boundary would remain unaltered for a long time. This is analogous to the boundary between the *Chloris/Howea* at Fred Nichols Garden described above.

Figure 35. Bimodal age distribution in *Howea forsterana* forest near Salmon Beach. Several decades of cattle grazing had destroyed all the small plants of *Howea* and other species. Because there are no adjacent paddocks with *Pennisetum* or *Stenotaphrum* the palms were able to regenerate from seed.

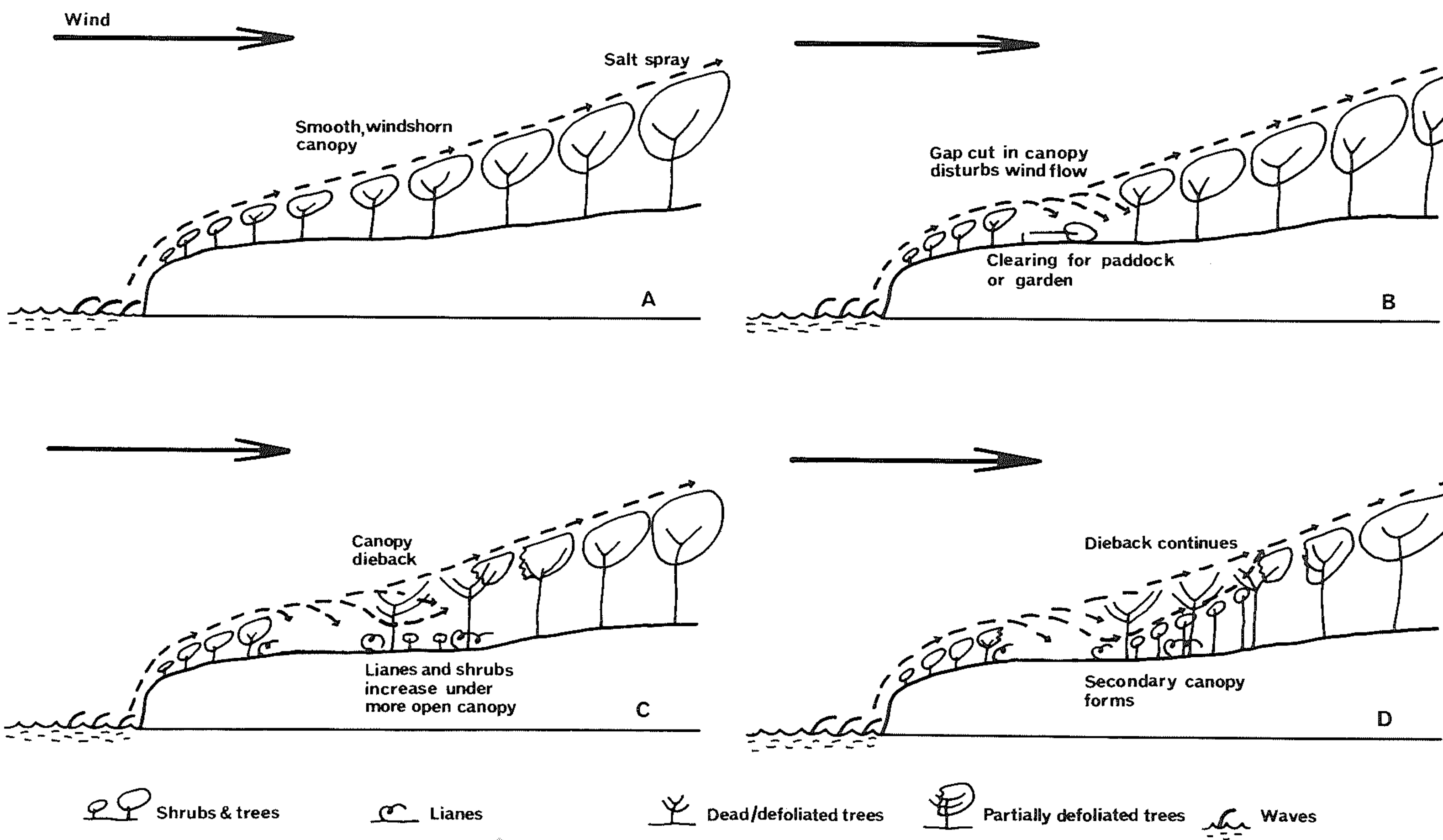

Figure 36. Secondary canopy formation in coastal forest disturbed by a clearing (A). Wind-borne salt blows through the previously intact canopy and starts progressive die-back of the canopy trees (B, Figure 37). Lianes and shrubs respond to the increased light by forming dense tangles (C, Figures 37, 38). Young canopy plants grow up through the shelter of these tangles and form a secondary canopy (D, Figure 39). This rises from the ground level at the edge of the clearing up to the original canopy. As long as the clearing remains unchanged, the secondary canopy will persist, but if the wind flow is altered again by altering the shape or size of the clearing, then a new secondary canopy will form.

Figure 37. Canopy dieback in *Cleistocalyx fullagari* and *Drypetes australasica* on the edge of a clearing on the exposed ridge below and west of Middle Beach Common. Shrubs, lianes and young canopy plants are forming a dense tangle out of reach of grazing cattle just beyond a fence (foreground).

Perhaps the most complex situation occurs on moderately exposed forest sites which are cleared or grazed. The interaction between wind, cattle, and shade stimulates the formation of what I call "secondary canopy". It is usually initiated by clearing and subsequent exposure of a wall of fresh or unconditioned vegetation to wind. If the clearing is small, then the wind streamlines are apparently unaffected and no damage occurs. But if the width is greater than 1 to 1½ times the height of the canopy, then the wind blows through the vegetation on the lee side of the clearing (Figure 36). Leaves on the exposed trees die giving the "die-back" (Figure 37) reported by

Figure 38. Tangle of lianes over shrubs and young trees in *Howea forsterana* forest about 10 m from the edge of the clearing in Figure 37.

Figure 39. Steeply rising secondary canopy in *Drypetes australasica-Cryptocarya triplinervis* forest near the edge of the clearing shown in Figures 37 and 38.

all observers from Foulis (1853) on. This allows more light to penetrate the canopy and a vine entanglement or shrubby understorey to develop (Figure 38). The height of this tangle is determined by the wind, so that it is lowest next to the clearing and rises into the forest. As seedlings of canopy plants grow, they form a new canopy line rising at a steep angle from the edge of the clearing up to the original canopy (Figure 39). This is the "secondary canopy". If the clearing is abandoned, then an old field succession would occur leading to eventual recovery of the original canopy line. As this line is an integrated long-term response to the wind, if the wind regime does not change, a similar line will be attained when succession is complete. Locally, for example, between "Pine Trees" guest house and Windy Point, up to three planes or secondary canopies have developed (Figure 40) in response to obstruction to wind flow leading to slightly different wind streaming patterns.

Figure 40. Wind flow around obstructions immediately north of Windy Point has lead to three planes of secondary canopy, after road construction and clearing on the windward side had exposed previously sheltered *Drypetes australasica-Cryptocarya triplinervis* forest.

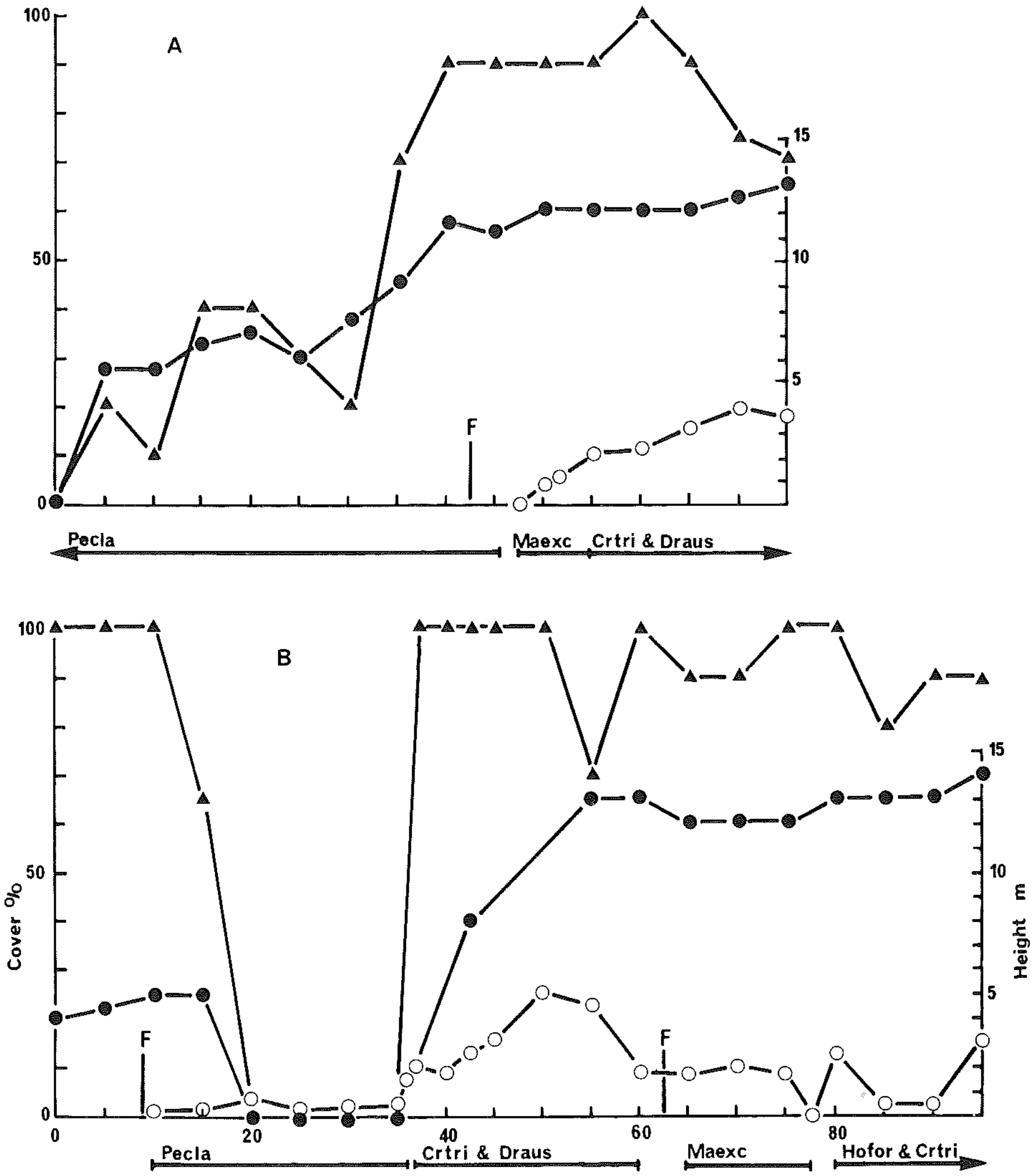

Figure 41. Distribution of canopy cover (▲), canopy height (●), and secondary canopy height (○) on two transects, A and B, measured above the south end of Middle Beach. Cattle graze to the left of the fences (F) on transect A, and between the fences on transect B. Solid lines under the figures indicate the distribution of the major secondary canopy species:

Crtri	*Cryptocarya triplinervis*	Maexc	*Macropiper excelsum* var. *psittacorum*
Draus	*Drypetes australasica*	Pecla	*Pennisetum clandestinum*
Hofor	*Howea forsterana*		

If grazing continues in the clearing then the results are not as simple and may be further complicated by fences. Two transects were measured on calcarenite soils above Middle Beach at the southern end of the Big Mutton Bird Ground. *Drypetes-Cryptocarya* forest has been grazed for many years and has been fenced since at least 1923 (Ferrier, 1923). Canopy height and cover, and secondary canopy height were measured at 5 m intervals on the transects (Figure 41).

On both transects the secondary canopy rises steeply towards the original canopy but does not reach it before falling again. The species measured are all canopy trees

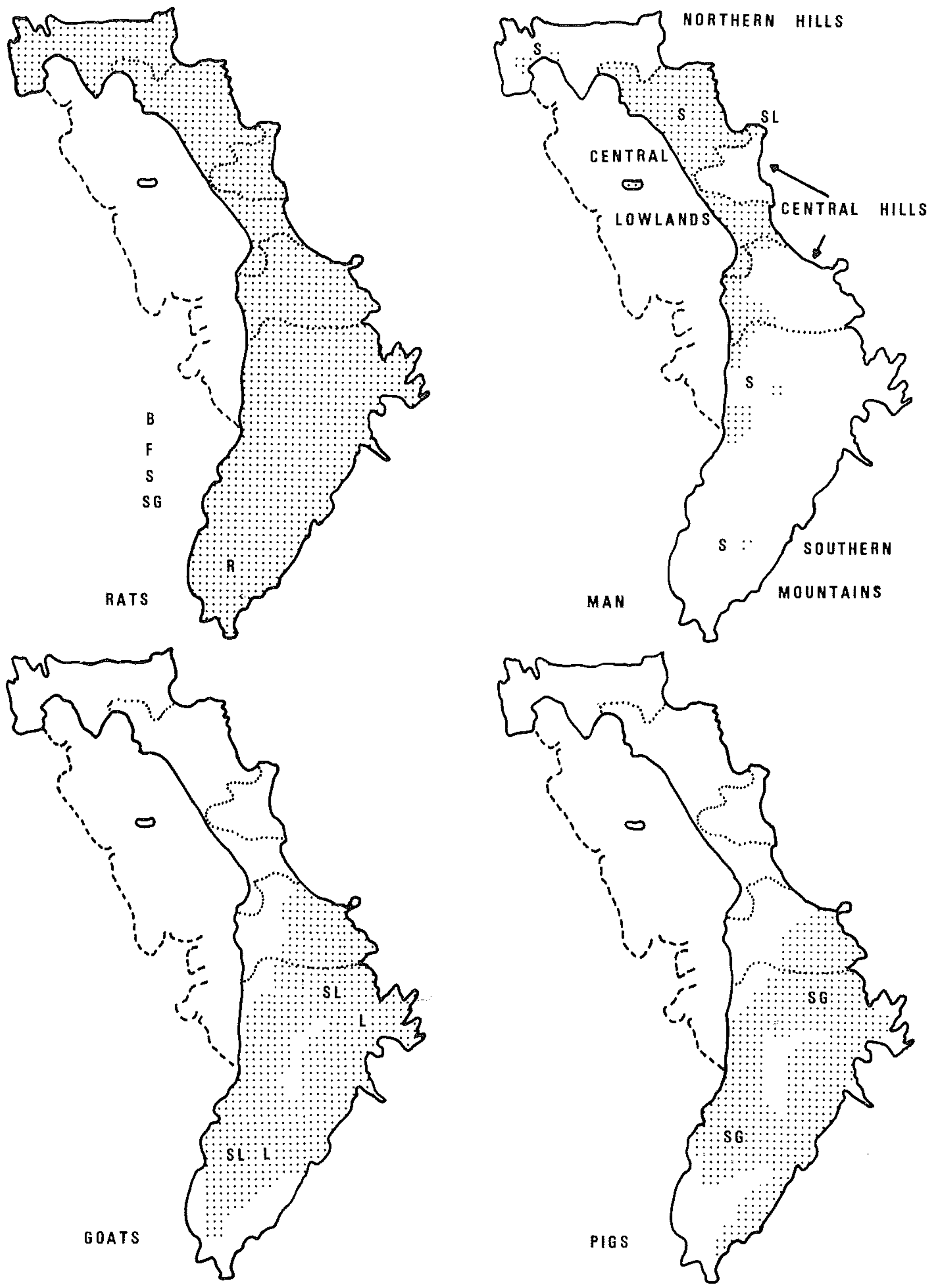

Figure 42. Generalized distribution of five animal predators (stippled) on the plams showing the parts of the plams (letters) attacked in different physiographic regions of the island. Insects are ubiquitous and are not shown. Distribution map for goats omits northern hills population which was exterminated in 1977. Not all palm-seeding areas are shown on the map for man. Different areas are harvested every few years, those shown being the major seeding areas. The four physiographic regions are described on pages 136-140.
Abbreviations and symbols

B	Flower buds	SL	Seedlings
F	Flowers	R	Rhachises
S	Seeds (on trees)	L	Leaves
SG	Seeds (on ground)		

. . . Boundaries of physiographic regions

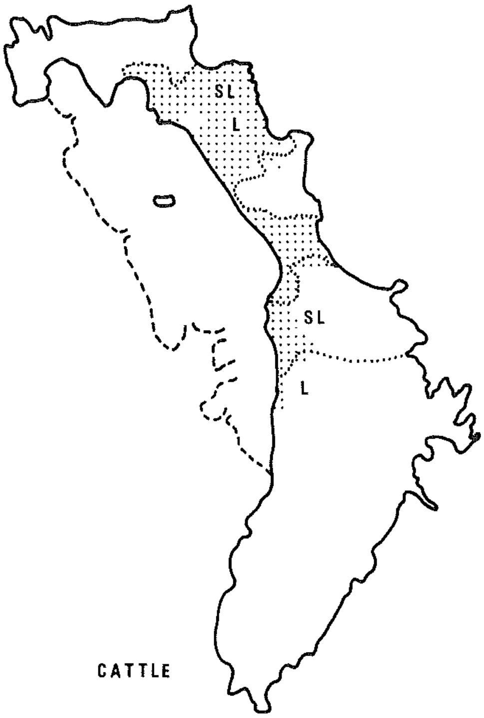

Figure 42 continued.

except for *Macropiper excelsum* var. *psittocorum*. *Macropiper* is a common understorey woody herb/shrub on the island, usually found in light breaks. The fenceline effect is more prominent on transect A than on transect B. On the former, *Pennisetum* barely penetrates the ungrazed forest but on the latter it does not. Transect B is somewhat unusual as some young canopy plants are inside the grazed area. Presumably, at some time in the past, cattle were not grazed in the paddock, and the *Cryptocarya* and *Drypetes* established inside the edge of the canopy where there was no competition from *Pennisetum*.

Palm-seeding and the palm forests

Harvesting and exporting of palm seeds began about 1890 and, with some interruptions, has continued to the present day. Basic information on the industry and seed yields is given in Pickard (1980). Four species are harvested; the quantities harvested are always in the order *Howea forsterana, H. belmoreana, Hedyscepe canterburyana* and *Lepidorrhachis mooreana*. Before the harvesting commenced the only predators on the palms were presumably insects; but now insects, rats, goats, cattle, pigs and man all attack the palms at various stages of growth.

The question I consider here is whether this combined predation is jeopardizing the long-term future of the palm forests. I shall only discuss *Howea forsterana* as the pressures on the other three species are considerably lower. The simple answer to the question is that undisturbed forests appear to be coping with predation, that is, there is adequate replacement of old trees. In stands disturbed by clearing and, or grazing, existing palms are not being replaced as they die.

To clarify this we need to consider those stages of the life history of the palm that are attacked (Figure 42). Insects attack buds, flowers, seeds and the trunks, but to an unknown degree. The palm forests and insects have coexisted on the island for a considerable time so they are probably in equilibrium. Rats eat every part of the palm except the leaves and trunk. Field evidence indicates that seeds are the most attractive to rats. Cattle and goats eat seedlings and leaves within reach. Fallen seeds are eaten by pigs. Finally, man harvests seeds and seedlings but also fells trees for clearings. The proportional effect of each animal depends on the location: in grazing paddocks, cattle predominate; in sparse stands in the northern hills, rats and goats; in sparse stands in the southern mountains, rats, goats and pigs; in dense accessible stands, rats, goats, man and pigs.

Only in paddocks grazed by cattle is there no sign of young and seedling palms (Figure 31). Thus it is clear that in these disturbed situations cattle, rather than rats or man, are limiting regeneration. In ''undisturbed'' areas where palms are attacked by rats, man, goats and pigs, there is a variable number of seedlings and young palms. For example in the Grey Face seeding area there are 826 ± 2145 seedlings* and 667 ± 635 saplings/ha (Pickard 1980, unpublished data) measured in 15, 5 m square quadrats. In the Clear Place seeding area at Valley of the Shadows there are sufficient seedlings that these are now being harvested.

Pigs and goats appear to be unimportant except locally. In the special case of Little Slope, where goats were much more abundant than usual, they removed all young plants of *Howea forsterana*. Clearly then, man only harvests the seeds which the rats leave; cattle, goats and pigs eat seeds and seedlings that escape both rats and man. The inherent difficulties of palm-seeding mean that only high-yielding and accessible palms are harvested. Fewer than 10 per cent of 300 trees in seeding areas measured each year for three years had seed yields exceeding 4 kg (Pickard, 1980). As most of these trees are subject to continual predation by rats, the remaining seeds are available for regeneration, which leaves ample stock for replacement of old palms.

I can see no reason why some island residents and conservationists assert that present levels of seed and seedling harvesting are detrimental to the forests. Available evidence shows that cattle grazing in paddocks, which are frequently poorly fenced, are the real problem. Better management, such as fencing off small enclosures, planting young palms and improving boundary fences would prevent deterioration of these areas. Rats are a different proposition. They are ubiquitous, omnivorous and virtually impossible to eliminate. Despite this, there is little evidence that the combined pressure of 60 years of rats' and 90 years of mans' predation have damaged the forests over most of the island. Rats have, however, seriously reduced the number of seeds available for harvest.

If future research demonstrates that harvesting is causing deterioration, seeding from natural stands should be phased out in favour of plantations. Suitable sites occur on seldom-used and unproductive grazing paddocks. In fact, there is considerable merit in this even if deterioration cannot be proven. Palms grown from seeds selected from trees known to be high-yielding should have higher-than-average yields when cultivated. Rat control would be simpler, cheaper and more effective in plantations than natural forests. This is a relatively simple and cheap method of effectively reducing pressure on the natural forests and increasing the total harvest and income.

Construction

Basalt and calcarenite have been quarried at several sites on the island for construction material. More recently the airstrip was built using both local and imported raw materials. The combined effect of all these quarries is quite low, but the sites show a range of responses. The critical factor is not the rock type but whether the adjacent area is disturbed. Quarries in or next to grazing paddocks or similar

*Seedlings defined as *Howea forsterana* up to 1 m high, saplings as up to 2 m but without a trunk.

Figure 43. Kirribilli was quarried for fill for the airstrip in 1975. Introduced grasses, particularly *Pennisetum* and *Stenotaphrum,* were allowed to colonize the area which adjoins the golf course (on the left). The stand of *Drypetes australasica-Cryptocarya triplinervis* forest in the rear is now exposed to winds and will very quickly start to die back.

grassed areas are colonized by the pasture grasses, usually *Pennisetum* or *Stenotaphrum.* Examples on calcarenite are at Neds Beach, Middle Beach Road and Kirribilli (Figure 43); on basalt at Windy Point and above Lovers Bay. In each case the quarry is invaded by the grasses although some other species also occur.

If the quarry is surrounded by essentially undisturbed vegetation, then it will be invaded by seedlings of native species and very few weeds. Small calcarenite quarries on Anderson and Middle Beach Roads are both recolonized by the surrounding forest species, for example, *Drypetes australasica, Cryptocarya triplinervis, Planchonella myrsinoides* and *Asplenium oblongifolium.* The largest quarry site on the island was cleared but never actually exploited. The Wood Paddock near Salmon Beach was intended as a source of basalt for construction of the airstrip in 1975. The forest was cleared, a few test trenches were dug, but the site was abandoned. No efforts have been made to restore the vegetation, but colonization until 1978 was by a mixture of mostly native species with some exotics. Provided the aggressive grasses do not become established the original vegetation should regenerate. By 1981, the proportions had changed considerably, with *Pennisetum* becoming dominant, particularly on the western portion of the site.

The airstrip was built on the low, flat ground south of Transit Hill. The corner of a relatively undisturbed *Drypetes-Cryptocarya* stand was cleared and the remainder exposed to the wind. The consequences are exactly as could be expected: progressive crown die-back, and vine tangles and secondary canopy formation. The stand of *Lagunaria patersonia* in the swamp behind the Blinky Beach sand dune was destroyed to improve safety (Figure 44). The top of the calcareous sand dune at Blinky Beach was removed to improve the safety for aircraft taking-off and landing. It was restored and planted with *Spinifex hirsutus* to stop sand drift. Restoration has been successful, drift is minimal. However, while *S. hirsutus* is a native grass and occurs on the sand-dune, most of the material planted was imported from the north coast of New South Wales (Soil Conservation Service of NSW, pers. comm.; R. Shick, pers. comm.). Any unique genetic differences in the Lord Howe population are now contaminated.

Figure 44. Remains of the *Lagunaria patersonia* swamp forest in Moseley Park after it had been cut down to improve safety at the southeast end of the airstrip in 1975. Compare with the photograph on p.178.

Tourism and attempts at aesthetic improvement

Some 4–5 000 tourists visit Lord Howe Island each year (Ashton, 1974). Although no visitor surveys have been conducted, it is obvious from talking to visitors that a large number come for the scenery, flora and birds (Figures 18, 19). The scenery is a mixture of forested hills and mountains, verdant grazing paddocks and ever-changing seascapes. What has been the effect of several decades of tourism on the environment?

The direct effects of tourists are minimal; most damage is a consequence of attempts to improve the scenery. The practice, if not the policy, of the Lord Howe Island Board from 1955 to 1978 has been to modify and destroy the natural vegetation, presumably in the belief that such modification enhances the beauty of the island. In 1963 native scrub on the hind-dune opposite the school was cleared and 200 New Zealand Christmas Bushes (*Metrosideros excelsa*) were planted in 1964 (Annual Report of the Lord Howe Island Board 1963, 1964). In 1981, 18 years after the shrubs were planted, the area is a closely mown turf of *Stenotaphrum secundatum* and *Pennisetum clandestinum* with some of the *Metrosideros* still surviving (Figure 45). Onshore winds have inhibited growth of the *Metrosideros* on the exposed shore. Further inland, the seaward edge of the native forest is exhibiting symptoms of die-back first described over 100 years earlier by Foulis (1853). Not only was the experience of the effects of foreshore clearing ignored but also the possibility of hybridization between the exotic *Metrosideros excelsa* and the two endemic species *M. nervulosa* and *M. villosa*. More recently the Board has attempted to correct this mistake and is now replanting various native species in the shelter of remnant shrubs. By 1981 several of these plantings were well-advanced demonstrating that restoration is possible. However, some island residents are still planting exotic plants such as *Nerium oleander* and *Erythrina* x *sykesii* on the foreshore about 300 m away (Figure 46).

Pennisetum clandestinum (Kikuyu Grass) and *Stenotaphrum secundatum* (Buffalo Grass) are the most abundant and widespread pasture grasses on the island.

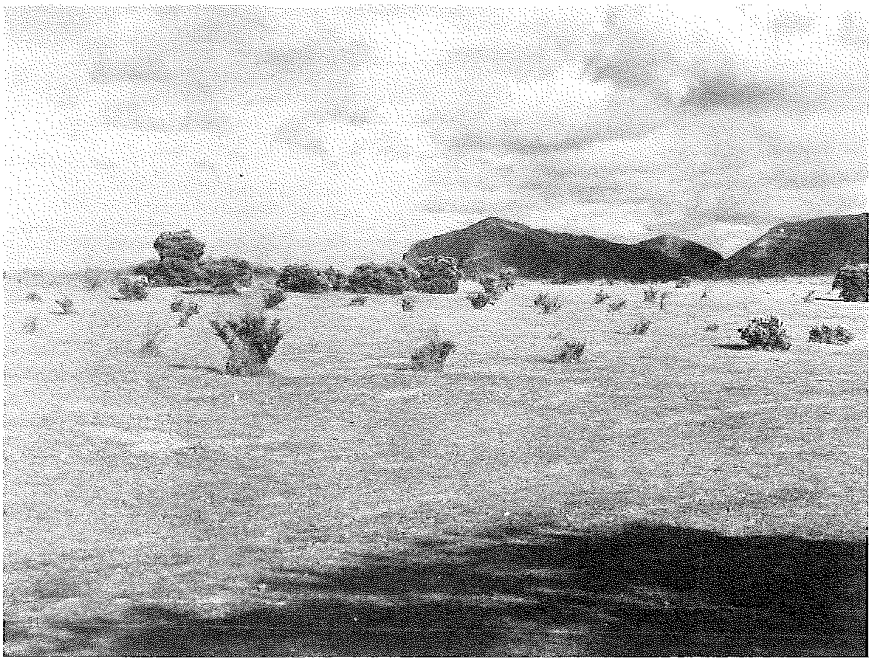

Figure 45. From 1955 to 1960, the hind-dune scrub was cleared from Lagoon Beach opposite the playing field and replaced with planted New Zealand Christmas Bush (*Metrosideros excelsa*). After nearly 20 years the bushes have scarcely grown. Regular mowing to maintain the lawn of introduced grasses prevents recolonization by native vegetation. More recently, the Board has begun a programme of replanting native shrubs and trees in this area.

Figure 46. An island resident cleared hind-dune vegetation behind Lagoon Beach near the main settlement to plant the area with exotics such as Oleander (*Nerium oleander*) and Coral Tree (*Erythrina* x *sykesii*). Norfolk Island Pines (*Araucaria heterophylla*) on the right were planted over 100 years ago.

Figure 47. There has been a belief that every patch of eroding soil on the island requires stabilizing and some residents have planted stolons of *Pennisetum clandestinum* to arrest what is a natural process. On Little Slope, this patch of *Pennisetum* just above the shore is spreading into the *Howea forsterana* forest and, if it continues unchecked, will spread along the length of Little Slope and become impossible to eradicate.

Figure 48. Behind Neds Beach the *Howea forsterana* forest at the northern end of the Big Mutton Bird Ground stops abruptly at the edge of regularly mown *Pennisetum clandestinum*. Lawns like this are common in the main settlement area of the island and frequent mowing prevents any regeneration of native trees. The dense palm forest is not invaded by the grass, presumably because there is insufficient light.

Both spread vegetatively and now cover most disturbed road verges, and similar sites. If left unchecked, the grasses grow into a tangled mass up to 1 m deep to the exclusion of other small plants (Figures 47, 49). When they are mown, they form attractive lawns (Figures 5, 48) and when grazed in paddocks, a rough pasture results (Figure 31).

Figure 49. Dense growth of *Chrysanthemoides monilifera* and *Pennisetum clandestinum* about 1 m high under *Drypetes australasica-Cryptocarya triplinervis* behind Lagoon Beach near the airstrip terminal.

Unrestricted mowing to maintain the lawns prevents regeneration because it kills any seedlings. However, the same effect results from no mowing because the vigorous grasses suppress seedlings by competition. There is no simple solution to the problem of regeneration of the infested areas. Some patches may be treated with herbicide and natural regeneration allowed, but this would be successful only in small isolated areas surrounded by an adequate source of seed of native plants. *Pennisetum* has been deliberately planted in several places because residents are unable to accept that erosion is a natural process and is not necessarily "bad". Small patches on Mutton Bird Point, Little Slope (Figure 47), and the Get-up Place on the track to Mount Gower, and the Lower Road were all planted to stop erosion. *Pennisetum* now covers virtually the entire summit of Mutton Bird Point, having spread rapidly from 1970 to 1980. The other sites serve as foci for the spread of the grass into adjacent uninfested vegetation. Herbicide treatment may be successful on these sites as they are isolated, and there are adequate seed sources for colonization by native species.

Several ornamental plants have become naturalized in both disturbed and undisturbed vegetation. Boneseed (*Chrysanthemoides monilifera*) was introduced to the island about 1935 as a garden plant and escaped to a few scattered sites along Lagoon Beach. The populations were static for many years but rapidly expanded after 1970 (Figure 49). Since 1975 the Board has been trying to eradicate the plant by tractor- and hand-pulling (Figure 50). This may lead to other problems, for example, invasion of the disturbed soil by *Pennisetum* or a number of other weeds. Tiger Lily (*Lilium formosanum*) was also introduced as an ornamental, but escaped; the plants flower profusely and seed prolifically. Like many other weeds, *Lilium* has spread south rather than north and is now firmly established in the southern mountains.

Boats, once essential for the island's economy, are now mostly used in the tourist industry. One exception is the lighters used for unloading cargo ships which anchor off the island. The main public jetty in the lagoon is frequently used, and some residents believe that turbulence created by boats is damaging the *Zostera-Halophila* community on the lagoon floor. I examined the community at several places including the jetty and saw no evidence of damage due to boats. In fact, some of the tallest and densest stands occur at the end of the jetty where the traffic is heaviest.

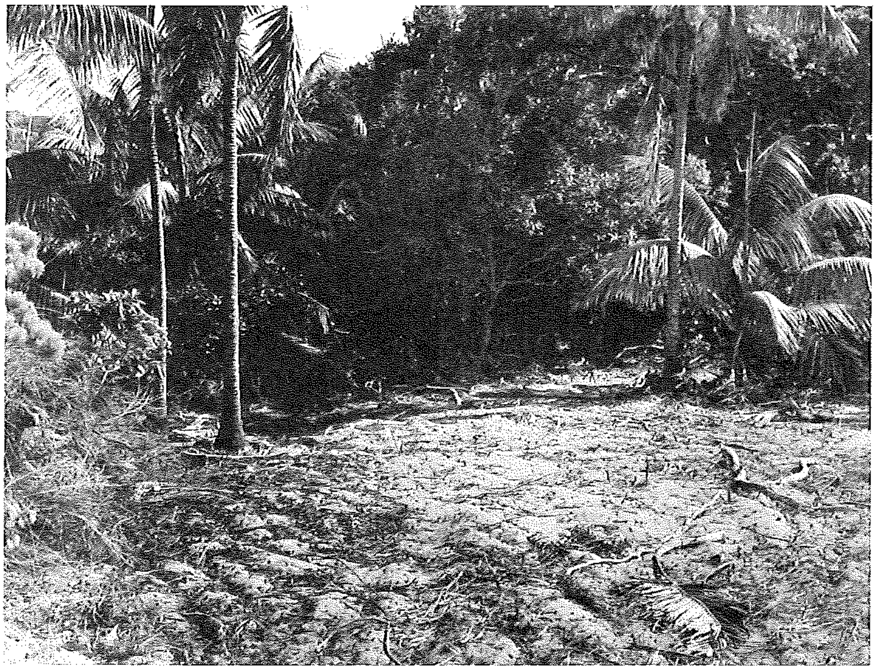

Figure 50. Since 1975 the Board has unsuccessfully tried to eradicate *Chrysanthemoides monilifera* from the island. This was a very dense stand of the shrub on the dune behind Lagoon Beach about 200 m south of the end of the airstrip. Because it was so dense and the individual plants so large, pulling with a tractor was necessary. However, the disturbed soil surface is an ideal seed bed for other weeds, and other methods of eradication may be indicated.

In December 1902, Edgar Waite (1902) commented on the community in Hunter Bay "at the north end of Lagoon are small masses of seaweed [sic] 3 or 4 feet in diameter. These wave their crest about in the wash of the waves and at low tide are barely covered." Today, the stands are virtually identical and there appears to be no evidence of disturbance (photograph, p.212).

THE FUTURE OF THE VEGETATION

The aim of this study was to describe and map the vegetation of Lord Howe Island. The description would be incomplete without some consideration of the future of the vegetation particularly as it could be affected by management decisions. I have discussed the effects of past management above; these have mostly been deleterious. Perhaps the major threat to the vegetation is from progressive dieback adjacent to clearings. Although it was recognized over 100 years ago, it is still largely ignored as a problem. In 1978 the Lord Howe Island Board commenced replanting native species on a few foreshore areas denuded of trees. This approach has been successful and should be extended to other areas on the island.

Tourists provide by far the largest income to the island. Many tourists come to look at a relatively undisturbed island with outstanding scenery and wildlife. I have found little evidence that the present numbers of visitors have significant impact on the vegetation. This is chiefly because they are actively discouraged from visiting many of the unsettled areas of the island. With planned management (for example, an extended network of marked walking tracks), many more tourists should be able to see more of the vegetation and wildlife with no increase in damage.

The palm seed industry is a major source of income to the Board for essential public works. I have discussed it elsewhere (Pickard, 1980) and will only restate here that the present levels of harvesting are not damaging the vegetation. Income from seeding should increase with a change from exploitative to conservative attitudes. Plantations and nurseries should be established. Even if plantations and/or a National Park were established, there is no ecological reason why both the traditional seed harvest and the more recent seedling harvest should not continue. After an establishment period of some 15 years (for *Howea forsterana*), plantations can be expected to supply sufficient seed for both nurseries and direct export. Similarly, other native plants could be grown in nurseries for export.

Much of the vegetation on Lord Howe does not occur in Australia, although similar types are found on other Pacific Islands. Therefore, in an Australian context, Lord Howe can be regarded as unique. This alone is sufficient justification for conservation. If one accepts the view that the best way to conserve species is to conserve their habitat, this provides further justification. Lord Howe has an endemic flora of some 60 vascular species and an unknown number of non-vascular species. About 20 of these endemics dominate the vegetation on some 860 ha (about 55 per cent of the island). Clearly, if we are to conserve this genetic diversity, we must conserve the vegetation.

Although the Environmental Survey recommended that a large proportion of the island be dedicated as National Park, this has not yet been done. The island has been nominated as one of ten areas in Australia warranting the status of World Heritage Areas, but at the time of writing (1981), acceptance of this by the New South Wales and Australian Governments was still awaited.

The prime responsibility of the Lord Howe Island Board at present is to look after the welfare of the residents. Under the same legislation the Board is required to manage the natural areas. However, the welfare of residents will always be the primary aim and frequently in conflict with conservation. There is no reason why the Board could not acquire the attitudes and skills necessary to manage the natural areas. But this would not diminish the conflict between the intangibles of conservation and the monetary value placed on welfare.

Dedication of these natural areas by the New South Wales Government as National Park carries a statutory requirement for expert conservation management. I believe that the correct action would be to create the National Park. The vegetation of Lord Howe has survived 140 years of settlement with relatively little damage. It would be regrettable if the information now available were not used to ensure its continued survival.

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This paper is based on my Master of Science thesis "Vegetation of Lord Howe Island". My supervisor was Dr Peter J. Myerscough of the Botany Department, University of Sydney. The comments of Dr Len J. Webb (CSIRO Rainforest Ecology Section) and Dr D. Walker (Research School of Pacific Studies, The Australian National University) have stimulated considerable improvement in the structure and organization of the paper. Dr Jocelyn M. Powell (Royal Botanic Gardens) took on the immense task of critically editing the manuscript and preparing it for publication.

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