Review of Palaeobotany and Palynology, 38 (1982) 1—21
Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

MODERN POLLEN RAIN AND RECENT VEGETATION HISTORY ON LORD HOWE ISLAND EVIDENCE OF HUMAN IMPACT

J R DODSON

School of Geography, University of New South Wales, Kensington, N S W (Australia)

(Received January 29, 1982, revised version accepted July 18, 1982)

ABSTRACT

Dodson, J R , 1982 Modern pollen rain and recent vegetation history on Lord Howe Island Evidence of human impact Rev Palaeobot Palynol , 38 1—21

The pollen representation of major plant taxa and the characteristic pollen assemblages of most of the major vegetation types on Lord Howe Island were studied by pollen analysis of eighteen surface samples It was found that five main vegetation groups could be identified from the pollen assemblages These were (1) a coastal herb, shrub and mangrove group, (2) the *Drypetes australasica—Cryptocaria triplinervis* and *Howea* spp palm forest, (3) the *Cleistocalyx fullageri—Linociera quadristaminea* rainforest, (4) the *Pandanus forsteri* palm forest, and (5) the montane gnarled mossy forest and *Hedyscepe canterburyana* palm forest These groups overlap considerably in species composition, and this overlap probably restricts their subdivision further These results were used to interpret three short pollen diagrams from Airport Swamp and Old Settlement Beach Swamp It was found that Airport Swamp and the western edge of Old Settlement Beach Swamp were largely man-made sites, with the latter coming into being as a result of a landslip The eastern part of Old Settlement Beach Swamp shows a natural change from *Cryptocaria* rainforest to *Howea* spp —*Pandanus forsteri* forest, probably as a result of changed drainage conditions This latter vegetation was then cleared to pasture Some of the implications of these changes to the flora and fauna are discussed

INTRODUCTION

Oceanic islands, particularly isolated ones, have always interested biogeographers They often have diverse biotas, high rates of endemism and rapid rates of gene flow through their populations The theory of island biogeography proposed by MacArthur and Wilson (1967) has now been subjected to some experimental testing (e g Connor and Simberloff, 1978, Simberloff and Wilson, 1970), and the results have demonstrated that important lessons can be learned which have application to all habitats which are distributed as islands (Diamond and May, 1976) Oceanic islands can therefore be viewed as one of the laboratories of biogeography

Lord Howe Island (latitude 31° 33'S, longitude 159° 5'E) lies 850 km northeast of Sydney (see Fig 1) The highest parts of the island are basalt peaks (Standard, 1963, Game, 1970) The southern end is dominated by Mt Gower and Mt Lidgbird which rise to 875 m and 780 m respectively The

0034-6667/82/0000-0000/$02 75 © 1982 Elsevier Scientific Publishing Company

northern end rises abruptly out of the sea to heights of 150 to 200 m Apart from Transit Hill (120 m) the central part of the island is composed of dunes of coralline sands An old sequence (dated at 20,700 ± 700 B.P by Squires, 1963) as well as the modern dune system occurs. The island therefore provides a wide range of habitats including mountain peaks and protected valleys, coastal dunes and mangrove swamps, and exposed cliff faces

The biota of the island have generated interest for some time since diverse biogeographical relationships are represented Explanations of these relationships (e g Paramonov, 1958, 1960, 1963) have been hampered by the paucity of studies on the fossil record on the island and remain speculative In nearly all plant and animal groups a significant, and sometimes dominant, endemic component attests to the long isolation of the island.

The work reported in this paper is concerned with laying the groundwork for vegetation history studies on Lord Howe Island and with studying recent vegetation change, particularly from the point of view of the impact of man in the settled parts of the island, and the implications of this for conservation of the vegetation

VEGETATION OF LORD HOWE ISLAND

The flora contains approximately 200 species of native and naturalised flowering plants spread across 87 families (Rodd, 1974). These occur in several structural vegetation units which include closed forest, open forest, closed scrub, broad-leaved herbland, grassland and various disturbed units of vegetation Often the boundaries between these structural types is not sharp and where cliff faces occur variants of all of the above may be found

Pickard (1974) has prepared a vegetation map of the island showing the distribution of sixteen vegetation types based on structure and floristics The main controls on their distribution appear to be relative exposure, altitude, soil type and the effects of human and animal interference (Pickard, 1974, 1976, Clark, 1974)

A typical vegetation transect from the highest parts of the southern mountains to sea level would probably show a shift from gnarled mossy forest of *Dracophyllum fitzgeraldii*, *Lepidorrhachis mooreana*, and tree ferns with abundant epiphytes, to *Hedyscepe canterburyana*, *Leptospermum flavescens*, *Metrosideros nervulosa* montane forest This grades into *Cleistocalyx fullageri—Linociera quadristaminea* closed forest and at lower or less protected sites into either *Drypetes australasica—Cryptocaria triplinervis* or *Howea* spp palm forest Two variants of the latter are found with *Howea forsterana* occurring on sites of relatively low slope angle and *H belmoreana* on steeper sites On lowland sites, too exposed for forest, a closed-scrub of *Melaleuca howeana—Cassinia tenuifolia* is found but this too gives way to natural grassland containing *Poa poiformis*, *Cyperus haematodes*, *Commelina cyanea*, *Lepidium howinsulae* and *Ipomoea cairica* on the most exposed sites which are subject to salt spray

Other vegetation types represented on the island include *Pandanus forsteri*, in poorly drained creek flats and sheltered gullies, *Aegiceras corniculatum* or

Avicennia marina var *australasica* mangrove communities in tidal waters, and *Boehmeria calophleba—Piper excelsum* closed scrub on a large western-facing slope on Mt Lidgbird.

MODERN POLLEN RAIN ON LORD HOWE ISLAND

The identification of vegetation types from fossil pollen assemblages requires information on the morphology of pollen types present, the relative pollen production rates and their transport and representation in deposition sites In practice all these details are never studied but are approximated by collecting modern or surface samples which collect and preserve pollen from within representative vegetation types This was the procedure followed here with the aim of establishing which vegetation types could and could not be clearly identified from modern pollen assemblages

Small yet diverse floras like that on Lord Howe should make possible the identification of many pollen grains to species level A reference collection of pollen and spores was prepared from as many flowering plants and spore-producing ferns as could be found between November 3rd and 14th, 1977 A total of 65 pollen and spore taxa could be identified within this reference collection, and these taxa represent approximately 225 species of flowering plants and ferns A more extensive and thorough investigation of the pollen and spore morphologies could undoubtedly increase the number of taxa identified with precision.

An attempt was made to collect several samples of each of Pickard's (Pickard, 1974) seventeen vegetation types (Fig 1) The choice of sample sites was aided considerably by Pickard's vegetation map. Lack of accessability prevented sampling from the *Boehmeria calophleba—Piper excelsum* closed-scrub and the *Halophila ovalis—Zostera capricorni* marine meadow vegetation In general, 3—4 sub-samples were collected from openings within each vegetation type and compounded to minimize over-representation of canopy taxa where samples were collected from around the base of a single plant In general, samples consisted of moss cushions, and whole cushions were collected to avoid the effects of differential sedimentation of pollen within the cushions (Crowder and Cuddy, 1973). At each site a list of species occurring within a 20-m radius was also compiled

The surface samples were prepared by boiling them in 5% NaOH for 10 min, then after using standard Erdtman's acetolysis procedure the residues were mounted in silicone oil (see Faegri and Iversen, 1975, or Moore and Webb, 1978, for details) Pollen was counted until at least 200 grains of woody taxa had been identified. Counts were then expressed as percentages of total terrestrial pollen and spores excluding Cyperaceae and psilate monolete spores which were found to be generally well over-represented A preliminary examination of the results showed that pollen assemblages did not differentiate among all vegetation types which were sampled Therefore, the eighteen surface samples were sorted into five groups based on the similarity of their pollen and spore composition (Fig 2) The vegetation type and composition

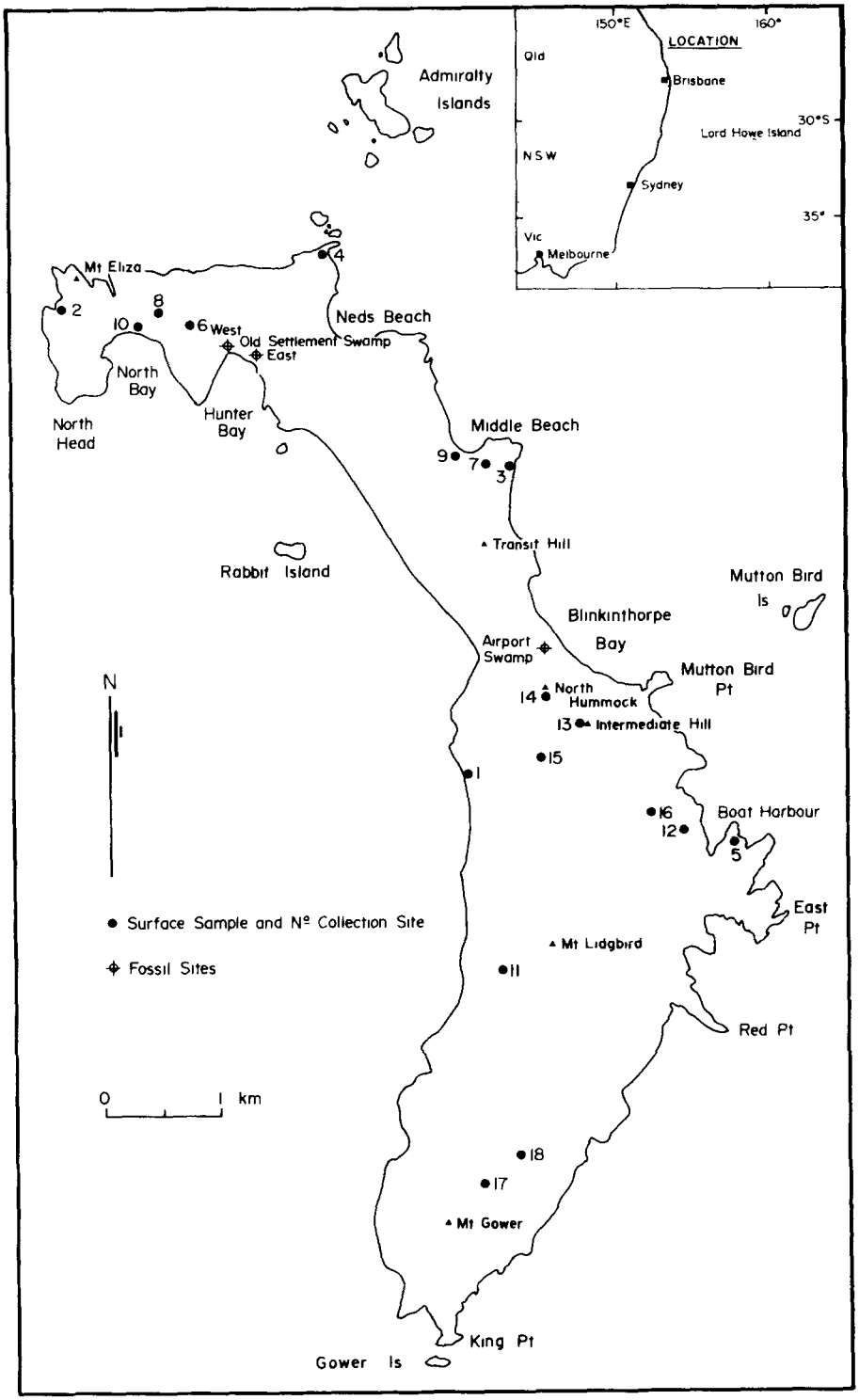


Fig 1 Map of Lord Howe Island showing locations of surface samples and fossil sites used in this study

with respect to the most abundant species around each surface sample are listed in Table I

Group A

This group of surface samples (Nos 1—5, Table I) was collected from a range of vegetation types which included mangrove vegetation, narrow sclerophyll scrub, broad-leaved herb vegetation and orthophyll short grass They typically occur close to the coast or on exposed basalt cliff ridges or faces The pollen assemblage is characterized by high values of Poaceae (>10%), Cyperaceae (75%) and the herbaceous taxa Chenopodiaceae, Asteraceae and Brassicaceae. *Melaleuca howeana* and Convolvulaceae were components near the coast, but *Aegiceras corniculatum* (in Myrsinaceae) was only weakly represented in the mangrove sample

Group B

Surface sample numbers 6—11 were from three main vegetation types the *Drypetes australasica—Cryptocaria triplinervis* closed forest, and the two palm forest types dominated by *Howea forsterana* and *H belmoreana* The spectra are dominated by Arecaceae pollen with values above 40% and up to 95% being recorded Other consistent values were 1—5% for Poaceae and Cyperaceae, but for the most part other taxa were poorly or patchily represented These samples to some extent reflect the mixed composition of the vegetation types but also demonstrate that important pollen taxa such as *Drypetes australasica*, *Cryptocaria triplinervis*, *Ficus columnaris*, *Randia stipulosa* and *Bubbia howeana* cannot be relied upon as indicators of these vegetation types unless their pollen occurs in large quantities

Group C

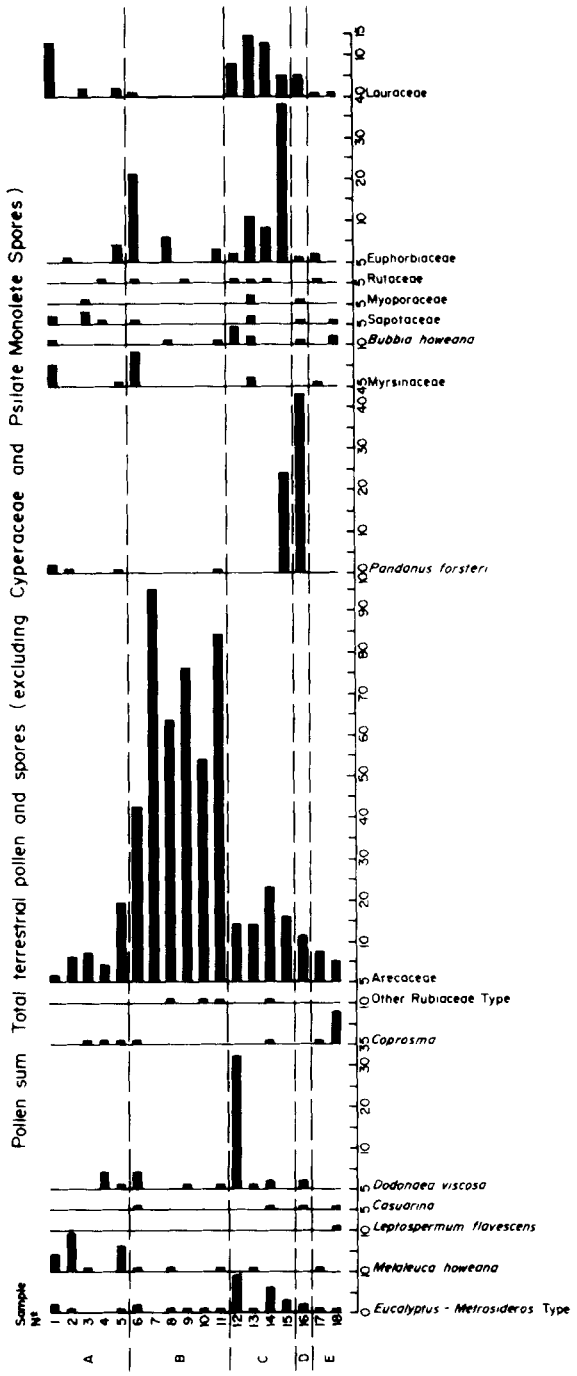
Surface samples 12—15 were collected from variants of the *Cleistocalyx fullageri—Linociera quadristaminea* closed forest The pollen of this forest type is characterized by Euphorbiaceae values of 2—11%, Lauraceae values of 8—14%, and Arecaceae values of 14—24% The two major species were very poorly represented and many of the secondarily important plant species, such as *Dodonaea viscosa*, *Ficus columnaris* and the Filicales, showed large variance in the pollen record These observations no doubt reflect the mixed composition and closed nature of this vegetation type

Group D

Surface sample number 16 was collected from *Pandanus forsteri* closed forest A value of 43% *Pandanus* pollen was recorded here, but a 24% figure was recorded from surface sample number 15, where *Pandanus forsteri* was a common component in the vegetation These observations suggest that *Pandanus* pollen is quite well represented

LORD HOWE ISLAND

Modern Pollen Rain Samples



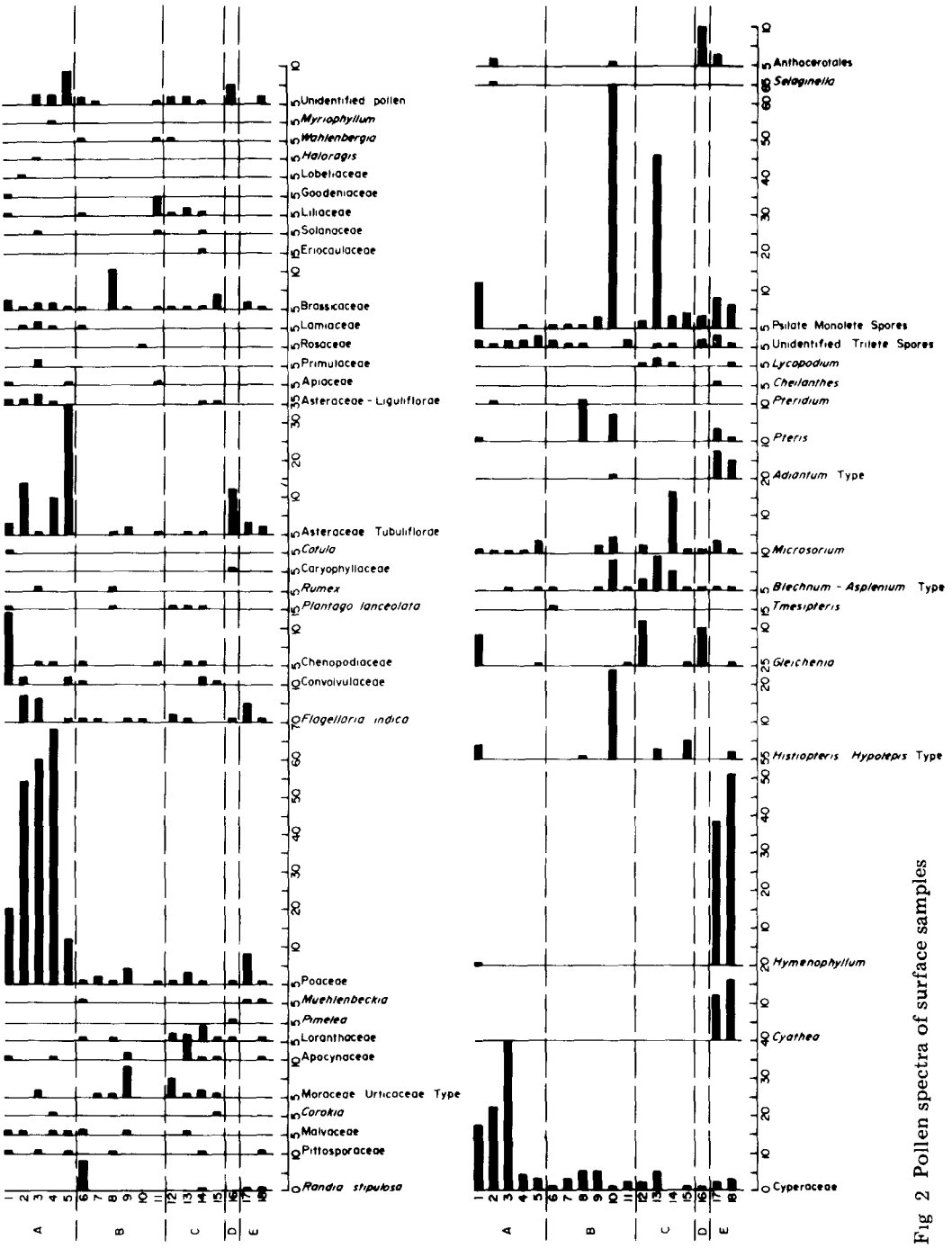


Fig 2 Pollen spectra of surface samples

TABLE I

Vegetation and major species present within 20 m of surface samples (vegetation type based on Pickard, 1974)

Surface sample No	Vegetation type	Major taxa present
1	*Aegiceras corniculatum*	*Aegiceras corniculatum, Salicornia quinqueflora, Sporobolus virginicus Ipomoea cairica, Melaleuca howeana*
2	*Melaleuca howeana—Cassinia tenuifolia*	*Melaleuca howeana, Cassinia tenuifolia, Ipomoea cairica, Scirpus nodosus, Leucopogon parviflorus*
3	*Poa poiformis*	*Poa poiformis, Melaleuca howeana, Ipomoea cairica, Cassinia tenuifolia, Trifolium repens, Oxalis corniculata*
4	Mixed herbs	*Poa poiformis, Lepidium howeiinsule, Solanum nigrum, Cyperus haematodes, Scirpus nodosus, Medicago* sp
5	*Melaleuca howeana—Cassinia tenuifolia*	*Melaleuca howeana, Cassinia tenuifolia, Scirpus nodosus, Cyperus* spp , *Apium australe, Pimelea congesta*
6	*Drypetes australasica—Cryptocaria triplinervis*	*Cryptocaria triplinervis, Howea forsterana, Drypetes australasica*
7	*Howea forsterana*	*Howea forsterana, Cryptocaria triplinervis, Ficus columnaris, Drypetes australasica*
8	*Drypetes australasica—Cryptocaria triplinervis*	*Cryptocaria triplinervis, Drypetes australasica, Baloghia lucida, Randia stipulosa, Howea forsterana*
9	*Drypetes australasica—Cryptocaria triplinervis*	*Drypetes australasica, Howea forsterana, Randia stipulosa, Lagunaria patersonia, Microsorium* sp
10	*Howea forsterana*	*Howea forsterana, Drypetes australasica, Myoporum insulare*
11	*Howea belmoreana*	*Howea belmoreana, Linociera quadristaminea, Cyperus* sp , *Cyclosorus nymphalis*
12	*Cleistocalyx fullageri—Linociera quadristaminea*	*Cleistocalyx fullageri, Linociera quad ristaminea, Dodonaea viscosa, Bubbia howeana, Machaerina insularis, Cryptocaria triplinervis*
13	*Cleistocalyx fullageri—Linociera quadristaminea*	*Cleistocalyx fullageri, Piper excelsum, Carex hattoriana, Linociera quadristaminea*
14	*Cleistocalyx fullageri—Linociera quadristaminea*	*Cleistocalyx fullageri, Howea forsterana, Dysoxylum pachyphyllum, Sophora howinsula, Microsorium* sp , *Pteris comans*
15	*Cleistocalyx fullageri—Linociera quadristaminea*	*Linociera quadristaminea, Metrosideros villosa, Bubbia howeana, Pandanas forsteri, Cyathea* sp , *Howea forsterana, Gleichenia* sp

TABLE I (*continued*)

Surface sample No	Vegetation type	Major taxa present
16	*Pandanus forsteri*	*Pandanus forsteri, Randia stipulosa, Carex hattoriana*
17	Gnarled mossy forest	*Lepidorrhachis mooreanum, Bubbia howeana, Hedyscepe canterburyana, Dracophyllum fitzgeraldii, Dysoxylum pachyphyllum*, Filicales
18	*Hedyscepe canterburyana*	*Hedyscepe canterburyana, Leptospermum flavescens, Metrosideros nervulosa, Bubbia howeana, Coprosma* spp

Group E

Gnarled mossy forest and *Hedyscepe canterburyana* palm forest, which are both closed-forest vegetation types, were studied with surface sample numbers 17 and 18 respectively The samples were collected from the summit of Mt Gower and their most striking component is their high representation of Filicales spores They contained 38—50% *Hymenophyllum*, 10—16% *Cyathea* and 5—7% *Adiantum* spores Arecaceae were present in relatively low values (5—7%) and would mostly have been derived from *Lepidorrhachis mooreanum* and *Hedyscepe canterburyana*. Important plant taxa from this region which were under-represented in the pollen data include *Leptospermum flavescens*, *Dracophyllum fitzgeraldii* and *Metrosideros nervulosa*

These results show that some of the vegetation types cannot clearly be delineated on the basis of pollen assemblages occurring within them The two major difficulties in this category concerned the grassland, coastal, and *Melaleuca howeana—Cassinia tenuifolia* groups, and the lowland closed forest group of *Howea* spp. palm and *Drypetes australasica—Cryptocaria triplinervis* In the case of the first of these it is probably a result of the open nature of these vegetation types, their close proximity to each other and the overlap in their floristic composition This apparently allows pollen from one vegetation type to be readily transported to the others The main problems in the lowland closed forest group probably result from considerable overlap in composition with respect to the major taxa and their poor pollen production and transport beneath the closed canopy Dodson (1976) reported a similar picture in the open and closed vegetation on Chatham Island Perhaps the only way of identifying the component vegetation types occurs where high values for one or more of the specific taxa is found

The *Cleistocalyx fullageri—Linociera quadristaminea, Pandanus forsteri*, and gnarled mossy forest—*Hedyscepe canterburyana* closed forests all appear to be distinguishable by their pollen assemblages. Appendix I lists the likely sources and transport characteristics of all of the pollen and spore taxa identified in this study

VEGETATION HISTORY

Three sets of samples were drawn from specially dug pit faces or cores in two swamps (Fig 1) Pollen preparation followed the procedure described for the surface samples except that those containing significant amounts of sand were first washed in 10% HCl and then allowed to soak for 24 h in 40% HF before the 5% NaOH treatment was applied

(a) Airport Swamp

The site is an almost circular depression located between the Blinkey Beach foredune and the road which skirts the eastern end of the airport runway Sediment depth was determined by probing at many locations across the swamp surface and was found to be relatively uniform and between 10 and 20 cm In all cases, a partly humified peat was found to overlie a thin heavy clay layer which in turn covered humic stained coralline dune sand. The pollen analysis samples were collected with the aid of a Russian sampler (West, 1968) from the centre of the swamp (Fig 3)

The swamp waters were found to support no aquatic plant species but contained the dead and fallen tree trunks of *Lagunaria patersonia*, and this fact suggests that the water level has recently risen and killed the trees. Most of the land immediately surrounding the swamp is a low grass–herbland, of mainly introduced species, used to pasture cattle This cleared area previously

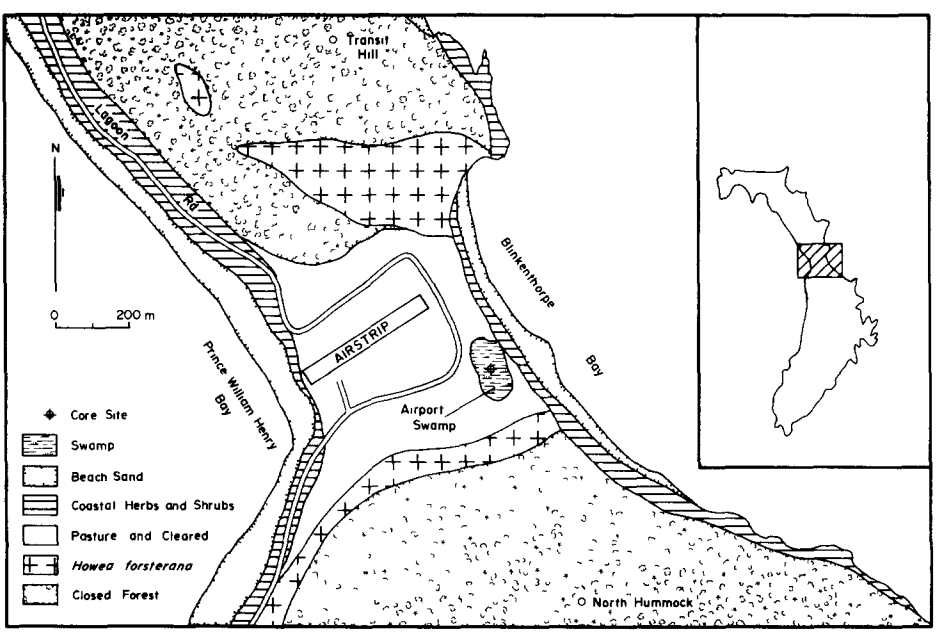


Fig 3 Site map of Airport Swamp area showing vegetation (partly after Pickard, 1974) and core location

supported *Howea forsterana* palm forest according to Pickard (1974) Remnants of this vegetation now occur within 150 m both to the north, on the footslopes of Transit Hill, and to the south, on the footslopes of North Hummock and Intermediate Hill The higher parts of these areas mainly support *Drypetes australasica—Cryptocaria triplinervis* closed forest The foredune to the east of the swamp is vegetated with a light cover of coastal herb and shrub vegetation, and large parts of it are presently undergoing management for dune stabilization by plantings of *Spinifex hirsutis*

The pollen spectra are dominated throughout by Poaceae, Asteraceae (Liguliflorae) and Cyperaceae pollen which are indicative of the vegetation presently surrounding the swamp (Fig.4) The Asteraceae (Liguliflorae) component is most likely derived from introduced plants and therefore indicates that the swamp sediments have been deposited since European occupation of the island Other indicators of the cleared and open nature of the vegetation include the low values of *Plantago lanceolata* and values of Arecaceae pollen below 30% In this context it is probable that the values of Moraceae—Urticaceae pollen were derived from *Urtica* spp. rather than from *Ficus columnaris* since the local area would have had no suitable habitat for the latter species

The whole history of the swamp, therefore, appears to be from the period of European occupation of Lord Howe Island The site most likely came into being as a result of man's disturbance of the site through clearing or by putting in the road There is no indication in the pollen record of what the vegetation was like before clearance to confirm Pickard's (1974) mapped unit for the area, but the swamp surface was probably covered with *Lagunaria patersonia* which was killed after decreased drainage away from the site occurred through man's activities

(b) Old Settlement Swamp

This swamp lies inland of the Old Settlement Beach foredune (Fig 5) Two pits were sunk at the eastern and western ends of the site and the pollen records from within them are hereafter referred to as the Eastern and Western Old Settlement Swamp sites, respectively. The deepest section of the whole of Old Settlement Swamp was located at the eastern end site. The samples from the western end were taken to compare sedimentation rates and differences in vegetation history across the surface of the swamp

(1) Eastern Old Settlement Swamp

This site was located close to a creek which must inundate the area after high rainfall events The sampling area was moist but was not underwater at the time of sampling The flooding creek probably brings pollen from the closed forests situated north of the swamp. The sediments consist of about 1 cm of dense root mat passing through a 1 cm transition zone to 28 cm of dark-brown clayey peat At 30 cm there is a sharp transition to white coralline beach sand

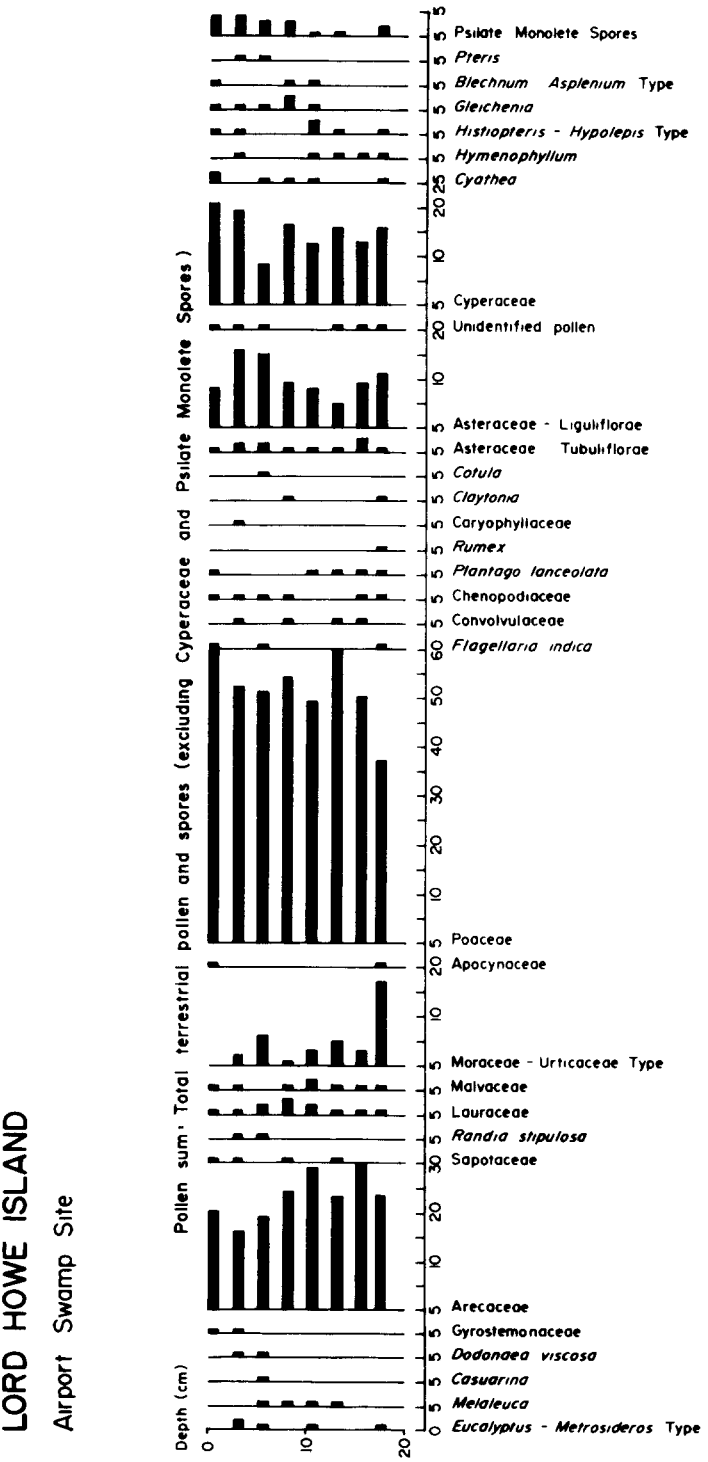


Fig 4 Pollen diagram from Airport Swamp core

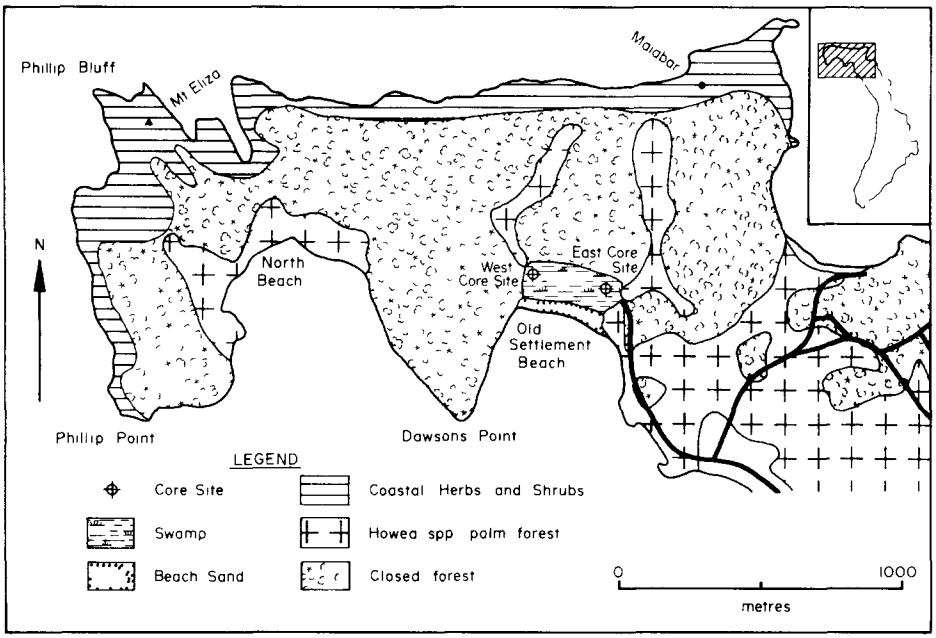


Fig 5 Site map of Old Settlement Swamp area showing vegetation (partly after Pickard, 1974) and fossil sites

At the time of European settlement, the site was occupied by *Lagunaria patersonia* swamp forest (Pickard, 1974) and it occurs within 50 m of *Howea* spp and *Drypetes australasica—Cryptocaria triplinervis* closed forests, to the inland side of the site, and within a few metres of herbaceous coastal vegetation to the south. The site is therefore well located to detect boundary shifts between several vegetation types Today the nearby vegetation is largely pasture and the nearest closed forests are 100—200 m to the north.

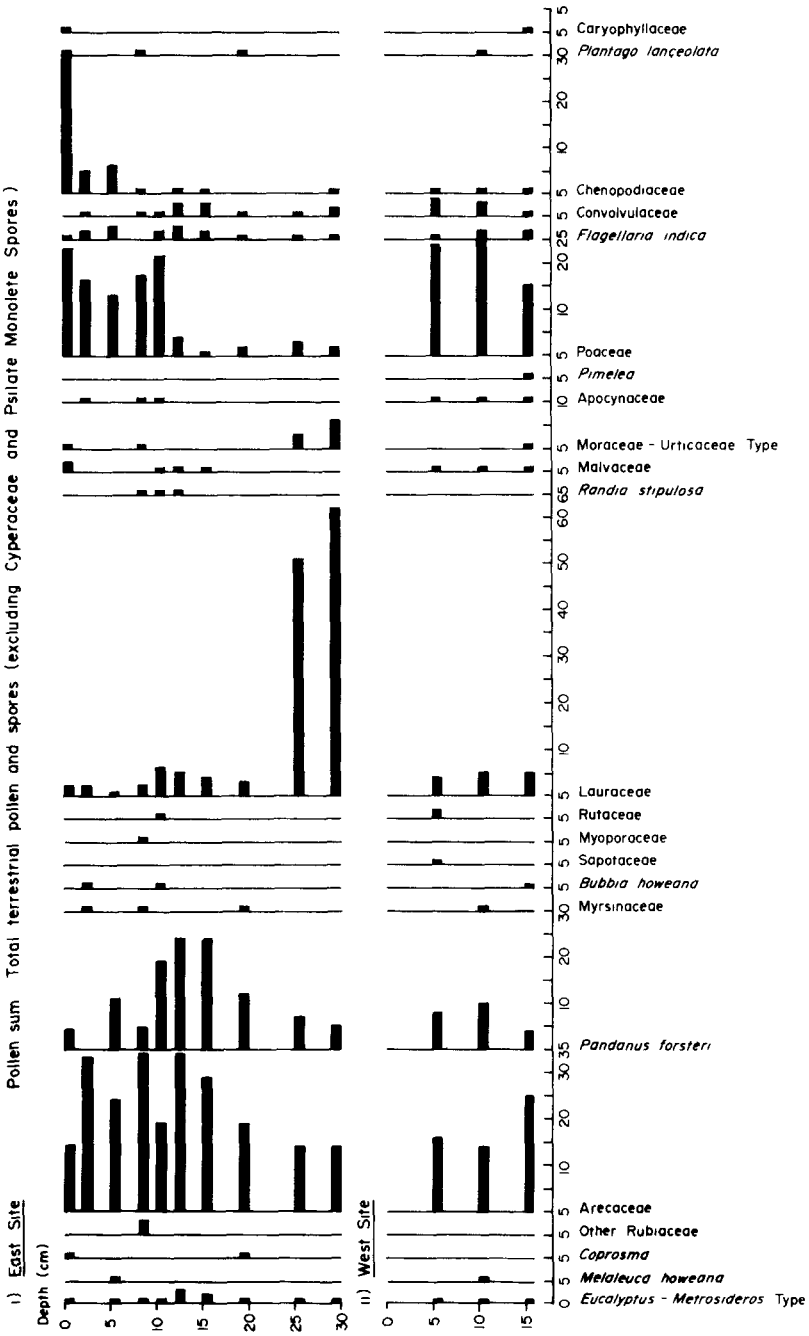
The pollen diagram (upper portion of Fig 6) shows a change through three types of pollen assemblage Between 30 and 25 cm Lauraceae pollen dominates the spectrum with low but significant quantities of Arecaceae, *Pandanus forsteri* and Moraceae—Urticaceae pollen These figures suggest that a closed forest containing *Cryptocaria triplinervis* and *Ficus columnaris* was initially on the site

The second assemblage between 25 and 10 cm depth is dominated by Arecaceae and *Pandanus forsteri* and has increasing amounts of Cyperaceae pollen. Malvaceae pollen also occurs for the first time and may be derived from *Lagunaria patersonia* The change to this assemblage almost certainly represents a shift to more swampy conditions in this section of Old Settlement Swamp.

The topmost pollen assemblage shows a decline in *Pandanus forsteri* and increases in Poaceae, Asteraceae (Liguliflorae) and Chenopodiaceae Arecaceae values remained as high as in the previous group. The topmost assemblage

LORD HOWE ISLAND

Old Settlement Swamp



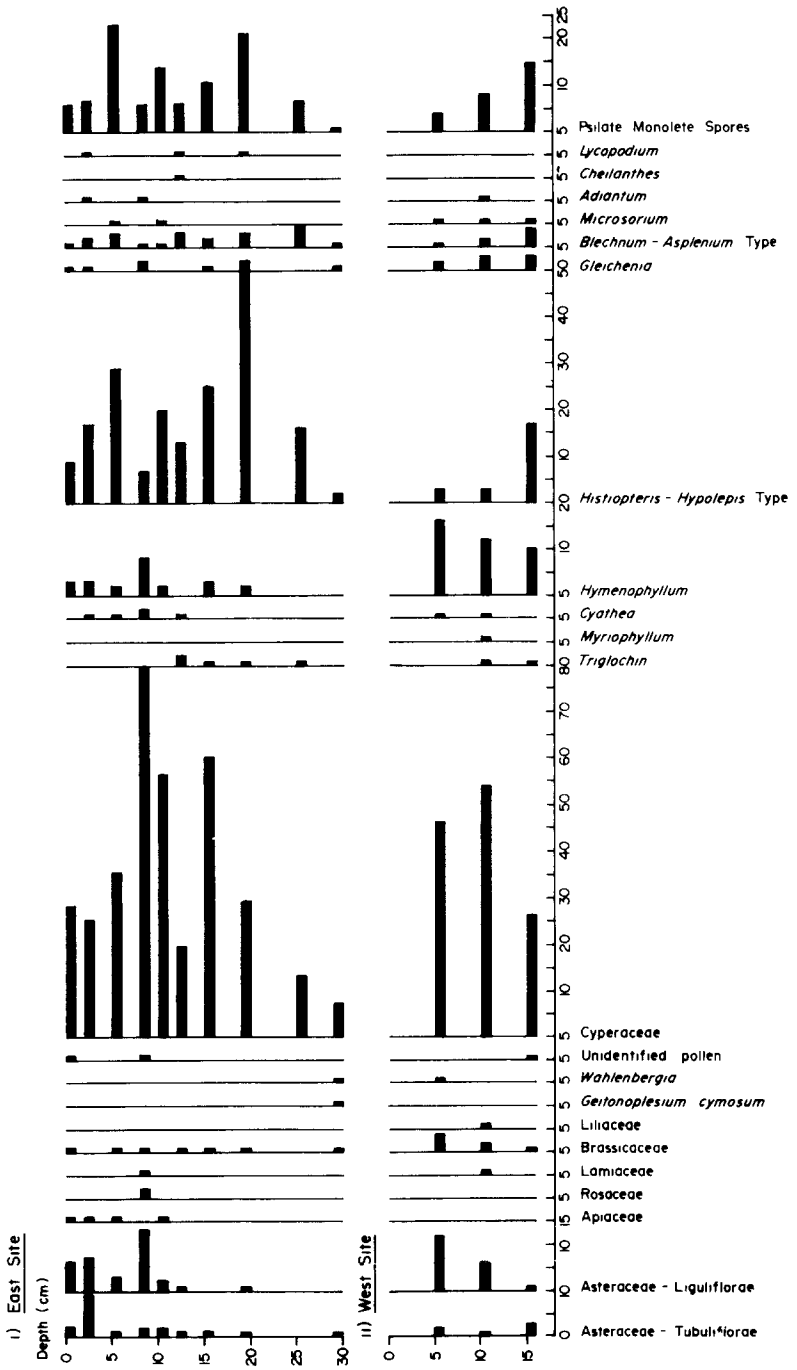


Fig 6 Pollen diagrams from Old Settlement Swamp sections

clearly represents the clearance phase and may possibly have been accompanied by partial draining of the area by Europeans

The presence of fern spores throughout the record shows that the site has remained close to rain forest and therefore the changes described most likely resulted from local events around the swamp rather than general environmental shifts

(2) Western Old Settlement Swamp

This site was located much closer to extensive closed-forest stands than the eastern site It is also near the small mangrove stand of *Avicennia marina* which today contains only about nine individuals. To the east of the site, swamp and pasture land occurs, while coastal herb vegetation covers the foredune on the southern side of the site

The geomorphological setting differs from the eastern site in that it occupies an old channel which probably drained the swamp before it was dammed by a landslip (Fig 5) This would have diverted waterflow to Hunter Bay away from this area toward the present outflow on the eastern end of the swamp The deepest set of sediments consisted of 0—16 cm of brown clayey peat overlying white coralline sand In view of their shallowness, and similarity of pollen content, only three peat samples were pollen-analyzed

The pollen diagram (lower portion of Fig.6) is dominated by Cyperaceae, Poaceae, Asteraceae (Liguliflorae) and Arecaceae pollen This fact suggests that all the sediments in the western end of Old Settlement Swamp were deposited after European clearance of the area The 16 cm of peat here is therefore equivalent to the 12 cm of peat at the eastern end of the swamp and indicates that there is a higher sedimentation rate due to slope inwash from the slope at the western end than there is deposition from the creek at the eastern end of the swamp

The fact that the pollen record contains only the European phase suggests that the landslip described above was a man-induced one The presence of palm pollen and Filicales spores shows that rain forest has occurred throughout the history of sedimentation at this end of the swamp

DISCUSSION

Most plant species on Lord Howe Island appear to produce low quantities of pollen and are therefore poorly represented in pollen assemblages The results of the modern pollen study, however, demonstrate that it is possible to distinguish most of the main vegetation types by pollen assemblage where species overlap is not too great.

Some of the modern samples contain pollen which was possibly derived from mainland Australia These include *Casuarina*, *Claytonia*, Goodeniaceae, Gyrostemonaceae and *Pteridium*, and possibly a *Eucalyptus* component in the *Eucalyptus—Metrosideros* Type, however, there is a plantation of eucalypts on the island. Dodson (1976) and Mildenhall (1976) have discussed aspects of pollen transport over similar distances from mainland New Zealand

to Chatham Island and along with Moar (1969) and Macphail (1979) have drawn attention to the fact that *Ampera xiphoclada*, *Casuarina*, *Eucalyptus* and Gyrostemonaceae pollen have made the journey from Australian to New Zealand sediments The Lord Howe Island data is therefore consistent with these findings However, *Claytonia* and Goodeniaceae pollen and *Pteridium* spores are not known to be well transported and their occurrence possibly indicates their source plants occur in the extant flora of Lord Howe Island and that as yet they have not been collected Dodson (1976) interpreted the consistent values (1—5%) of long-distance transported pollen to Chatham Island as indicative of relatively low production of pollen by forest vegetation there Perhaps the same holds true for Lord Howe Island vegetation compared, at least, to Australian mainland sclerophyll vegetation

The studies of the modern pollen rain clearly demonstrate that pollen analysis can be profitably carried out on Lord Howe Island to describe, with some precision, the dynamics and history of its vegetation The present study concentrated on applying the modern pollen results to the surface organic deposits of the island The dated organic soil described by Squires (1963) would probably yield pollen so there appears to be some scope for applying these results much further back into Lord Howe Island's past

The short vegetation histories described above have a number of lessons about the impact of man on Lord Howe Island There is no archaeological evidence to refute the notion that the first people to set foot on the island were Europeans in the late eighteenth century There were no native terrestrial mammals and thus the vegetation was not adapted to influence from large animals — and hence, was likely to be very sensitive to the effects of man and his introduced animals such as cattle and goats

The eastern site of Old Settlement Swamp showed a significant change from *Cryptocaria* rain forest to *Howea—Pandanus* rain forest which was not accompanied by any pollen from introduced species This fact suggests that it was a natural change not related to any human interference. The development of swamp conditions or prolonged flooding of the area could have induced such a change This is followed by a decline in palm rain forest to grassland, accompanied by pollen from introduced species, and shows the change to have been caused by humans The deposits at the western site came into being after a small landslip blocked and diverted the flow of a small creek to Hunter Bay. As all this deposit contained pollen from introduced species, it is probable that the slip was man-induced

This landslip is probably the main reason that *Avicennia marina* is now so precariously placed on Lord Howe Island Mangroves in general require prograding coastlines in order to reproduce and grow successfully (e g Ranwell, 1972) On Lord Howe Island today, *A marina* is represented by about nine individuals growing along the western edge of Hunter Bay toward Dawes Point This is a rocky and eroding coast, but, before the landslip it would have been supplied with sediment by the creek system Perhaps the answer to the survival of *A marina* lies in re-opening of the original creek outlet

Another species in trouble on Lord Howe is *Lagunaria patersonia* It is widely planted today but the swamp forests it formerly occupied are gone

However, the opening up of these areas plus the formation of the new swamp at the airport (Airport Swamp) appears to have provided new habitats for fresh-water birds such as waders and ducks which in the past were occasional visitors Man has not only helped to destroy or alter habitats, but has also created new opportunities for both desirable and undesirable species

ACKNOWLEDGEMENTS

I wish to record my thanks to Tony Rodd (N S W National Herbarium) for plant identifications, Chris Myers and Suzanne Rose for pollen preparations, Kerry Morrison for data preparation, and Kevin Maynard and Maria Rose for diagrams and typing the manuscript The project was supported by a grant from the School of Geography, University of N S W., research vote

APPENDIX I

Pollen and spore taxa identified from Lord Howe Island showing possible source plants and representation of pollen with respect to source plant abundance in vegetation Representation +++ = over represented, ++ = well represented, + = under represented

Taxon	Representation	Source
Adiantum	+++	low ferns in closed forest
Anthocerotales	+++	liverworts on damp ground
Apiaceae	+	herbs, mostly native species, in grassland and shrubland
Apocynaceae	++	mostly *Parsonsia straminea* var *glabrata*, an epiphyte
Arecaceae	++	*Howea* spp in lowland closed forest, *Hedyscepe canterburyana* and *Lepidorrhachis mooreana* in montane closed forest
Asteraceae (Liguliflorae)	++	introduced herbs
Asteraceae (Tubuliflorae)	++	native and introduced shrubs (*Olearia* spp) and herbs
Blechnum—Asplenium Type	+++	ground ferns or epiphytes in closed forests
Brassicaceae	++	native and introduced herbs in grassland and disturbed areas
Bubbia howeana	+	small tree in closed forest
Caryophyllaceae	+	introduced herbs in grassland, cleared or disturbed areas
Casuarina	+++	long-distance transport from Australia
Cheilanthes	+++	ground ferns in rock crevices
Chenopodiaceae	++	native and introduced herbs of swampy or disturbed areas
Claytonia	+++	swamp herb, perhaps long-distance transport from Australia as not known in flora
Convolvulaceae	+	*Calystegia* spp or *Ipomoea* spp of sea-shore or grassland

Taxon	Representation	Source
Coprosma	++	shrubs of scrubs of closed forests
Corokia carpodetoides	+++	small tree of upland closed forests
Cotula australis	+++	herbs of coastal vegetation
Cyathea	++	tree ferns of upland closed forests
Cyperaceae	+++	sedges of swampy areas or ground cover in closed forests
Dodonaea viscosa	++	shrub of closed forests
Eucalyptus—Metrosideros Type	+++	*Eucalyptus* from Australia or Lord Howe Island plantation, *Metrosideros* from upland closed forests
Euphorbiaceae	+	trees or shrubs of closed forests, or introduced taxa in disturbed locations
Flagellaria indica	++	tall herb of disturbed closed forests
Geitonoplesium cymosum	+++	epiphyte of disturbed lowland closed forests
Gleichenia	+++	ground fern in closed forests
Goodeniaceae	+++	apparently long-distance transport from Australia, as not known in flora
Gyrostemonaceae	+++	long-distance transport from Australia
Histiopteris—Hypolepis Type	+++	ground ferns
Hymenophyllaceae	+++	epiphytes on trees and tree ferns of closed forests
Lamiaceae	+	*Westringia fruticosa* shrubs or herbs in disturbed areas
Lauraceae	+	mostly *Cryptocaria triplinervis*
Liliaceae	+	*Dianella intermedia* in upland closed forest, introduced *Asparagus* spp in disturbed areas of lowland closed forests
Lobeliaceae	+	*Lobelia alata* var *alata* a herb
Loranthaceae—Viscaceae	+	long-distance transport from Australia or *Korthalsella japonica*
Lycopodium	+++	fern allies, ground cover
Malvaceae	+	includes *Lagunaria patersonia* or *Hibiscus* spp (trees) and introduced shrubs and herbs
Melaleuca howeana	++	shrub on exposed areas, especially near coast
Microsorium	+	ground fern and epiphyte in closed forests
Moraceae—Urticaceae Type	+	*Ficus columnaris* (Moraceae) — trees in lowland closed forest, *Boehmeria calophleba* (Urticaceae) shrubs in upland scrub or herbs of disturbed areas
Muehlenbeckia	++	herbs of disturbed areas
Myoporaceae	+++	*Myoporum insulare*, tree of coastal and closed forests

APPENDIX I (*continued*)

Taxon	Representation	Source
Myriophyllum	+++	long-distance transport from Australia as not known in local flora
Myrsinaceae	+	*Aegiceras corniculatum* (mangrove) or *Rapanea* spp , shrubs in closed forests
Pandanus forsteri	++	palm occurring along creek systems
Pimelea congesta	+	small shrub in closed forests
Pittosporaceae	+	small trees in closed forest
Plantago lanceolata	+++	introduced herb in disturbed areas
Poaceae	++	widespread, native and introduced species, rare in closed forests
Primulaceae	+	mainly introduced *Anagallus arvensis*
Psilate monolete spores	+++	various Filicates, ground cover and epiphytes
Pteridium	+++	long-distance transport from Australia
Pteris	+++	ground ferns of closed forests
Randia stipulosa	+	small tree in closed forests
Rosaceae	+	mainly introduced *Duchesnia indica* in disturbed places
Rubiaceae	+	introduced *Coffea arabica*, or native *Psychotria carronis*
Rumex	+	introduced herbs in disturbed areas and pasture
Rutaceae	+	shrubs in various closed forests
Sapotaceae	+	mainly *Planchonella myrsinoides* in closed forest
Selaginella	+++	fern allies on damp and open ground
Tmesipteris	+	epiphytes in closed forest
Triglochin striata	++	herbs of swampy areas, particularly near coasts
Unidentified pollen	Various	mainly tricolpate and tricolporate pollen from various families
Wahlenbergia	+	herbs on open ground, rocks and grassland

REFERENCES

Clark, S S , 1974 Pattern analysis of the vegetation In H F Recher and S S Clark (Editors), Environmental Survey of Lord Howe Island D West, Government Printer, Sydney, N S W , pp 37—46

Connor, E F and Simberloff, D S , 1978 Species number and compositional similarity of the Galapagos flora and avifauna Ecol Monogr , 48 219—248

Crowder, A A and Cuddy, D G , 1973 Pollen in a small river basin Wilton Creek, Ontario In H J B Birks and R G West (Editors), Quaternary Plant Ecology Blackwell, Oxford, pp 61—77

Diamond, J M and May, R M , 1976 Island biogeography and the design of natural reserves In R M May (Editor), Theoretical Ecology Principles and Applications Blackwell, Oxford, pp 163—186

Dodson, J R , 1976 Modern pollen spectra from Chatham Island, New Zealand N Z J Bot , 14 341—347
Faegri, K and Iversen, J , 1975 Textbook of Pollen Analysis Munksgaard, Copenhagen, 3rd ed
Game, P M , 1970 Petrology of Lord Howe Island Part 1 The younger volcanics Bull Br Mus Nat Hist , (Mineral), 2 1—284
MacArthur, R H and Wilson, E O , 1967 The Theory of Island Biogeography Princeton University Press, Princeton, N J
Macphail, M K , 1979 Two additional Australian pollen types in New Zealand N Z J Bot , 17 221—223
Mildenhall, D C , 1976 Exotic pollen rain on the Chatham Islands during the Late Pleistocene N Z J Geol Geophys , 19 327—333
Moar, N T , 1969 Possible long distance transport of pollen to New Zealand N Z J Bot , 7 424—426
Moore, P D and Webb, J A , 1978 An Illustrated Guide to Pollen Analysis Hodder and Stroughton, London
Paramonov, S J , 1958 Lord Howe Island, a riddle of the Pacific Part I Pac Sci , 12 82
Paramonov, S J , 1960 Lord Howe Island, a riddle of the Pacific Part II Pac Sci , 14 75
Paramonov, S J , 1963 Lord Howe Island, a riddle of the Pacific Part III Pac Sci , 17 361
Pickard, J , 1974 Vegetation map and notes In H F Recher and S S Clark (Editors), Environmental Survey of Lord Howe Island D West, Government Printer, Sydney, N S W , pp 27—36
Pickard, J , 1976 The effect of feral goats (*Capra hircus* L) on the vegetation of Lord Howe Island Aust J Ecol , 1 103—114
Ranwell, D R , 1972 Ecology of Salt Marshes and Sand Dunes Chapman and Hall, London
Rodd, A N , 1974 Checklist of angiosperms In H F Recher and S S Clark (Editors), Environmental Survey of Lord Howe Island D West, Government Printer, Sydney, N S W , pp 21—25
Simberloff, D S and Wilson, E O , 1970 Experimental zoogeography of islands A two year record of colonization Ecology, 51 934—937
Squires, D F , 1963 Carbon 14 dating of the fossil dune sequence at Lord Howe Island Aust J Sci , 25 412—413
Standard, J C , 1963 Geology of Lord Howe Island J Proc Soc N S W , 96 107—121
West, R G , 1968 Pleistocene Geology and Biology Longman, London