Catastrophic disturbance and vegetation on Little Slope, Lord Howe Island

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Abstract

Little Slope is a series of debris avalanche deposits below basalt cliffs 700 m high at the southern end of Lord Howe Island (31°35'S 159°05'E). There are five distinct physiographic areas on the slope, each separated by sharp boundaries which mostly correspond to boundaries between features on the cliffs above. The physiography is a consequence of a series of landslides of different, but unknown, ages. A model of the physiographic history is presented.

Each physiographic area supports a different vegetation community, also separated by sharp boundaries. The present structure of two communities, Melaleuca howeana scrub and Howea forsterana forest, is a consequence of damage by feral animals. Melaleuca scrub has replaced Cyperus lucidus sedgeland destroyed by goats (Capra hircus) browsing from 1914 until their extermination in 1955. Howea forest has a markedly unimodal age distribution with very few small individuals of the dominant palms. This is a result of the combined effects of browsing by goats on small palms, and seed predation by black rats (Rattus rattus) from the 1920s, preventing regeneration.

Unless rat numbers are periodically reduced to reduce seed predation, regeneration may be insufficient to guarantee long-term survival of the Howea forest.

Introduction

Vegetation is not static, it changes continually in response to changes in the environment. Thus the past history of an area is often a strong determinant of the structure and floristics of the current vegetation. Whether one can decipher the history and apportion cause depends on the particular area and its vegetation, and on a certain amount of luck. The evidence of a certain stage may have been destroyed by subsequent events. This is particularly true of slow changes induced, for example, by climatic changes. If there are no suitable ponds or lakes for preservation of pollen, or ancient trees with suitable growth rings it is unlikely that one will ever establish the full sequence of events and vegetation history.

Catastrophic changes in the environment are usually rapid and allow little or no time for vegetation adjustment. Such rapid environmental changes often affect only relatively small areas and cannot be regarded as regional or zonal events. For example, volcanoes are often rather small but over a period of time, lava or ash from a single, active vent may cover a substantial area. Landslides and rockfalls rarely cover more than a few tens of hectares but wreak catastrophic changes to vegetation in their paths. A notable example occurred in Chile in 1960 when mass movement caused by an earthquake swarm affected over 25,000 ha (Veblen & Ashton 1978).

Invasion by predators may be equally catastrophic and may affect or cover wide areas (Elton 1958). If the invasion has occurred in modern times then one may be able to document it, otherwise it may well remain undetected.

The effects of invasion of remote islands by predators are well known, but often more than one species of predator has invaded. The subsequent interactions are rarely described.

Lord Howe Island (31°35'S 159°05'E), in the South Pacific Ocean has suffered the usual fate of oceanic islands settled by western man — introduction of alien plants and animals. Most of the exotics are of little consequence but three animals — rats, goats and pigs — have caused considerable

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changes in the vegetation. The effects of goats (Capra Hircus L.) on the vegetation of the island have been described (Pickard 1976) but further observations on an isolated section of the island revealed that the changes were more complex than believed earlier.

On Little Slope, at the southern end of the island, there is evidence of a long history of landslides and rockfalls and a more recent history of invasion by goats and black rats (Rattus rattus Frisch.). This paper presents descriptions of the physiography and the vegetation of Little Slope and historical interpretations of the present vegetation patterns between and within communities. In particular, I examine the role of catastrophic changes induced separately and collectively, in the vegetation by land-slides and feral animals.

Methods and Results

Little Slope was visited three times: 13–14 February 1971, 9–11 October 1975 and 7 March 1977. In 1975 the vegetation was sampled using 43 sites each 5 m² arranged 25 m apart in transects (Fig. 1). Although most of the transects are parallel they are unaffected by the few parallel rills in the centre of the slope.

Floristic data were classified by a polythetic agglomerative program, and ordinated by a principal co-ordinate analysis using the TAXON package on CSIRONET (Williams 1976, Dale et al. 1979). Only species occurring on more than five sites were included in the analyses.

The 1977 visit was to establish a long term study of seed yield of thatch palm (Howea forsterana) (Pickard 1980). (Flowering plant nomenclature follows Jacobs & Pickard (1981). Authorities for ferns are given in Table 1). On Little Slope a total of 50 palms were selected 10 m apart in three transects. Seventeen other transects were established elsewhere on the island using the same method. Transect I on Little Slope is identical with one of the 1975 transects, transect II is parallel to the coast and

FIG. 1. Little Slope showing sites, transects and physiography. On inset map of Lord Howe Island arrow indicates Little Slope, crosses indicate location of other relevant transects, GC = Golf Course, GF = Grey Face, FFS = Far Flats South.
TRANSECT III is close to another of the 1975 transects (Fig. 1). Transects I and III were designed to sample variation from the shore to the cliffs at the top of the slope, transect II was intended to examine midslope variation. Each of the 50 sampled trees was permanently marked and the seed harvested and weighed. Seed was harvested in March 1977, April 1978 and April 1979. Variation in individual seed size and weight was not considered.

Density of adult (trunk visible) and seedling/juvenile (no trunk visible and leaves <1.5 m long) palms was estimated in quadrats 5 m square at 25 m intervals along the 1977 transects. The structural types of vegetation of the slope was mapped from air photographs and field observations (Pickard 1974).

Physiography

Little Slope consists of a series of debris avalanche deposits below cliffs of Tertiary basalt up to 700 m high at the southern end of Lord Howe Island. The Slope, which is roughly rectangular with an area of 17.6 ha, has a maximum altitude of c. 100 m. The Slope can be divided into five distinct areas (Fig. 2).

(a) Boulder slope. Against the cliff at the northern end a boulder slope c. 160 m wide runs from sea level to 100 m elevation. All but a 25 m strip is vegetated. The angular basalt boulders are up to 3 m (but generally 0.25-0.75 m) across. Soil occurs at the surface on the vegetated section but not on the bare strip where there are deep interstices. Above 100 m altitude this slope rapidly steepens into the next zone.

(b) Rampart and cave. An almost vertical wall c. 30 m high of unsorted boulder debris forms a rampart across the front of a large overhang or cave. The outer face of the rampart is vertically below the lip of the top, or outer limit, of the overhang. Thus the rampart is protected from erosion from water cascading down the cliffs during storms. The northern
and southern ends of the rampart coincide with permanent water drips from the cliffs. Behind the rampart the ground drops c. 5 m to the sandy floor of the cave.

(c) Palm forest. Directly below the southern end of the large overhang in the cliffs above (Fig. 2) the northern boulder slope ends abruptly. The slope increases, boulders at the surface are generally considerably larger, and the slope is clad with palm forest. The area commences immediately above the steep cliff c. 25 m high of poorly sorted rubble behind the beach. The slopes here are not as simple as in the first area; scree, rock slab outcrops, avalanche debris and swampy creeks all occur, but the boulders dominate the slope. Some soil is present, filling spaces between the boulders. Slabs of basalt outcrop in shallow creek gullies and become more numerous towards the top of the slope until they merge into the base of the cliffs.

In the south there is another sharp boundary into the Potato Hills. This boundary is directly below the northern ledge of a large, saucer-shaped depression (Big Pocket) in the cliffs 500 m above (f).

(d) Potato Hills. This area is characterized by steep narrow ridges and ravines running from the beach to the foot of the cliffs. The very unstable and actively eroding slopes of debris avalanche material are poorly sorted mixtures of boulders in a clay- and silt-sized matrix.

(e) Basalt boulder beach. Running the length of Little Slope is a beach c. 20 m wide of basalt boulders. The rocks up to the limit of wave action are rounded and beyond this they are angular. From the southern end of the Slope to the northern edge of the palm forest the beach is backed by a crumbling cliff 10–15 m high of poorly sorted avalanche material. Below the northern boulder slope the beach merges into the slope with only change in angularity and gradient to mark the change.

The remarkable sharp boundaries and collinearity of boundaries on the Slope and the cliff above are discussed in more detail below.

Vegetation

The vegetation of Little Slope mirrors the physiography with each area supporting a different community separated by sharp boundaries (Fig. 3). This is true of both the computer and the subjective classifications. The upper levels of the computer classification are shown in Fig. 4 with a broad interpretation of the final groups. The two-way table shows good concentration of site and species groups.

The three-group level of the site classification is essentially structural: scrubs, weedy and complex non-palm forest, and simple palm forest. The first division in the species analysis is on habit. The larger group of 21 species (A, B and C) is diverse with six trees, three vines, five ferns and five herbs (Table 1). This is characteristic of lowland forests on Lord Howe Island (Pickard in press). The other group of 14 species (D, E and F) is typical of scrub and herb communities.

![FIG. 3. Distribution of site-groups of classification. Letters indicate subjective site-group of each site. M = Melaleuca closed scrub, P = Poa herb vegetation, D = Drypetes-Cryptocarya low forest, F = Ficus high forest. H = Howea forest. Thick boundaries show 3-group level after reallocation.](image-url)
The ordinations of sites and species mirror the
classifications. Of particular interest is *Howea for-
sterana* which forms a one-species group in the
inverse (species) classification and is isolated on all
axes in the inverse ordination.

As the computer and subjective classifications are
so similar the subjective alliances only will be de-
scribed but the descriptions refer equally to the com-
puter groups.

(a) **Closed scrub Melaleuca howeana alliance (site
group 1, species group D).** This scrub is found
predominantly on the boulder strip at the northern
end of Little Slope but also at the top of the slope
beneath the cliffs (Fig. 3). A sparser community
 grows on Potato Hills at the southern end of the
slope. Generally this closed community has a
smooth, dense canopy.

(b) **Herbs Poa poiformis alliance (site group 2,
species groups E and F).** Herb vegetation covers the
exposed edges of Little Slope behind the beach, bare

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**TABLE 1. Composition of inverse (species) groups**

| Group | No. of Species | Composition |
|-------|----------------|-------------|
| A     | 10             | *Boehmeria calophleba, Cryptocarya triplinervis, Cypersus lucidus, Diplazium melanochlamys* (Hook.) Moore, *Elaeocarpus costatus, Ficus columnaris, Malaisia scandends, Microsorium diversifolium* Wild., *Pandorea pandorana, Pteris comans* Forst. f., |
| B     | 1              | *Howea forsterana* |
| C     | 10             | *Adiantum hispidulum* Sw., *Asplenium australasicum* (J. Sm.) Hook., *Balogia lucida, Carex hattoriana, Commelina cyanea, Drypetes australasica, *Eupatorium adenophorum, Leu-
copogon parviflorus, *Lilium formosanum, Parsonia straminea.* |
| D     | 3              | *Cassina tenuifolia, Melaleuca howeana, Pilotum nudum* (L) Beauv. |
| E     | 4              | *Asplenium lucidum* Forst. f., *Peperomia urvillei, Poa poiformis, Solanum nodiflorum.* |
| F     | 7              | *Carpobrotus glaucescens, *Conyza bonariensis, Nicotiana debneyi, Oxalis corniculata, *Rumex brownii, Sonchus oleraceus, *Spoobolus africanus.* |

*Naturalized.
boulders in the north and Potato Hills. The outer face of the rampart in front of the large cave in the north supports sparse grass and herb vegetation. Below the permanent water drips, the vegetation is richer and several soft shrubs and herbs grow luxuriantly. Nitrophilous herbs grow on the floor of the cave where faeces and urine from nesting sea-birds and goats have enriched the soil.

(c) Low forest Drypetes-Cryptocarya alliance (site group 3, species groups B, C and E). This low forest is a somewhat depauperate version of the most widespread community on Lord Howe Island (Pickard in press). On Little Slope it is a transition between the scrub vegetation and the forests. Although it is shown only in the south between the main palm forest and Potato Hills (Fig. 4), finer sampling would have revealed more examples between the palm and scrub at the top of the slope.

(d) High forest Ficus alliance (site group 4, species groups A and B). Huge individuals of *Ficus columnaris* cover areas up to 100 m diameter to the virtual exclusion of all other trees. These individuals form a band near the top of the slope above the *Howea* forest (Figs 2 and 4). In open patches between the *Ficus* some palms occur.

(e) Palm forest Howea alliance (site group 5, species group B). Below c. 70 m altitude *Howea forsterana* dominates the slope to the exclusion of all other trees except *Ficus columnaris* (Fig. 2). The palm forest is remarkably uniform. Stem diameter, height, stand density, and basal area show no trends along the transects, with three exceptions. The decrease in density up transect III is significant (*P*<0.05) using the Cox and Stuart sign test (Bradley 1968). Density decreases from north to south on transect II, and basal area decreases up transect III but neither trend is significant.

Height of palms can be used as a fair approximation of age (Tomlinson 1961). On Little Slope the stem height frequency distribution, and hence the age class distribution, is truncated and exhibits small dispersion (Fig. 5). Three palm transects further north on the island (Grey Face, Far Flats South and Golf Course, Fig. 1) have a wider range of age classes (Fig. 5). Golf Course is similar to Little Slope but is severely disturbed by grazing and mowing. The uniform structure, low seed yields and truncated age class distribution are indicative of disturbance by either seed predators and/or grazing animals.

**Origin of Little Slope and inter-community pattern**

The sloping piles of boulders and debris making up Little Slope came from collapse of the basalt cliffs above. These debris avalanche deposits have been weathered and eroded to different extents suggesting that a series of events was involved. Heterogeneous non-sorted angular material at 100 m elevation precludes marine origin on two grounds — the shape of the particles and the lack of evidence on Lord Howe Island of such a marine transgression. The following explanation accounts for the field observations of physiography and vegetation.

The first stage is the collapse of the cliffs to form a talus (Fig. 6a). Eventually the talus supported *Howea* forest. A rock fall at the northern end of the Slope created the large overhang on the cliffs, the northern boulder slope and the sharp boundary (Fig. 6b). Subsequently the northernmost section eroded leaving the rampart in front of the cave as the sole remnant of the original surface of the debris. *Cyperus* sedgeland covered most of the area. A slip-circle failure and rockfall from the top of the cliffs at the southern end created both Big Pocket and the debris for Potato Hills (Fig. 6c). Erosion of this debris gave the present ravine/ridge topography of the Potato Hills.
Catastrophic disturbance and vegetation

The final step in formation of inter-community pattern was the first biotic step — introduction of goats (Capra hircus) in 1914. The Melaleuca scrub covering the northern area replaced Cyperus lucidus sedgeland (Pickard 1976). In 1910, before the introduction, and in 1921, seven years after the introduction of goats, the area supported a dense cover of C. lucidus but by 1939 this had been destroyed by browsing goats. Between 1955 (when the goats were exterminated) and 1970 Melaleuca colonized the denuded boulder slope (Pickard 1976).

With the exception of the goat introduction the absolute dates of these events are presently impossible to fix. There are no relevant radiocarbon dates and subfossil bird bones in the caves behind the rampart are all from extant species (Fullager et al. 1974). However, the relative ages can be deduced from slope stability and degree of erosion.

The Melaleuca forest has several unusual features which require explanation. The age distribution is truncated and unimodal (Fig. 7), there are very few seedlings (e.g. on Little Slope, n=21, mean seedling density/ha is 495 ± 618 with a range 0–2000 compared with Grey Face, n=15, where density is 827 ± 2146, range 0–8400) and very few seeds ripen on the palms. It has been previously concluded (Pickard 1976) that browsing by goats had caused the truncated age distribution of palms. However, since goats were exterminated in 1955, ample time has elapsed for regeneration to take place. Elsewhere on the island a bimodal size class distribution can occur within 20 or 30 years of exclusion of cattle (Fig. 8).
FIG. 7. Thatch palm (*Howea forsterana*) forest on Little Slope showing lack of seedlings and young plants in 1977.

FIG. 8. Bimodal size distribution in palm forest near Far Flats in 1977, a few years after cessation of several decades of cattle grazing.
Pigs (*Sus scrofa* L.) were released on Little Slope several decades ago but were exterminated a few years later so they are unlikely to have exerted a lasting effect. Black rats (*Rattus rattus*) invaded Lord Howe from a beached ship in 1918 and quickly spread throughout the island (Hindwood 1940). Available evidence suggests that seed predation by rats has prevented regeneration in *Howea* forests on Little Slope.

In 1922 an island resident reported (in a letter to R. Hough, who subsequently published it in the *Evening News, 25 July 1922*): 'Last year the islanders gathered 342 bushels (12.43 m\(^3\)) of seed (from Little Slope) but this year the yield was eight bushels (0.29 m\(^3\)). The next crop which should be in the green is not in sight. Everywhere there is evidence of the depredation of the rats.' During the present study virtually no ripe palm seeds were seen on Little Slope as is shown by seed production data from the 50 sampled trees (Table 2). In 1977 two island assistants and I saw partially eaten, unripe seeds of the 1978 crop marked with rats’ incisor teeth.

| TABLE 2. Seed production (kg) from 50 sample trees on Little Slope |
|----------------------|----------------------|
|                      | 1977     | 1978     | 1979     |
| mean seed production | 0        | 0        | 0.73     |
| range                | 0        | 0 -3.0*  | 0 -5.5   |

*Five trees with seed.

These two observations, separated by 50 years, imply that rats consume virtually all seeds. It is possible that the decline in seed yield in 1922 was partially caused by droughts which occurred in 1917, 1918 and 1921. As *Howea* takes four years from bud initiation to seed ripening, a drought at a critical physiological phase in any one of these years could reduce the seed yield. However, even in drought years, trees protected from rats have higher yields than unprotected trees (B. Thompson pers. comm.) and it is highly unlikely that the virtual lack of regeneration for 22 years (1955–77) can be attributed solely to droughts. Seed predation by rats is a more likely cause.

This is supported by more recent (1980, 1981) good harvests of palm seed from Little Slope following an intensive poisoning program.

These observations are synthesized into a model (Fig. 9) explaining the pattern within the community. Up to 1955, rats ate palm seed on the trees and on the ground, and goats browsed young plants from seed that rats did not eat. Together, the two animals stopped all regeneration. After the extermination of goats in 1955 rats continued to eat all seeds except those few which escaped their attention. On Little Slope rats alone could eventually have caused the same unimodal distribution if goats had not been present. Young seedlings would have matured but no seeds would have been available for germination.

![FIG. 9. Interpretation of the history of the present structure and speculation on future structure of *Howea forsterana* forest on Little Slope. Before 1913 (1) the forest contained all age classes of palms but by 1922 enough seeds and seedlings had been eaten by rats and goats to simplify the structure (2) Goats were exterminated in 1955 and only adult palms remained (3) Continuing seed predation by rats prevented any regeneration and in 1977 the structure remained the same as in 1955 (4) If rats are poisoned now or if rats had not been present in 1955, stage (5) would follow within a few years. Subsequently stage (6) would occur if poisoning is maintained. Eventually the forest will become uneven-aged again but if rat control ceases, the structure will revert to stages (3) and (4). (Data from Oliver 1916, N. Fenton pers. comm. and field observations.)](image-url)
Discussion

Catastrophic disturbance is clearly the major factor in the present physiography and vegetation of Little Slope. Future landslides and rockfalls will doubtless alter the area but not in an unpredictable manner, since the scheme outlined above for the formation of the Slope will also apply in the future. Biotic disturbance is more amenable to control and there is now sufficient knowledge for some discussion of the future effects of rats on the vegetation.

To the palms there is no difference between goats browsing young plants, rats eating seeds, and human harvesting of seeds. All are examples of predation and, taken together, strongly affect forest composition. This predation is modern and considerably younger than the palm stands, which developed free from this predation. Unless seed predation is periodically reduced to allow sufficient seedlings to germinate and establish in the next decade, the palm forest on Little Slope may not survive beyond the life of the present trees.

Finally, it is worth noting that Little Slope provides yet another example of the inherent instability of natural systems. It is a good example because several changes, with different causes, have occurred over a long time-scale. To assume stability is fallacious and those who hope for it are doomed to disappointment.

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