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VEGETATION CHANGES INDUCED OVER TEN YEARS BY GOATS AND PIGS AT PORT ROSS, AUCKLAND ISLANDS (SUBANTARCTIC)

Summary: Marked sites established around Port Ross in 1973 were re-examined in 1983 to measure changes in the vegetation and assess the impact of goats and pigs. Goats had not increased in numbers, nor extended beyond their earlier range, but they were seen higher on the Hooker Hills. Pigs were scarce, but their sign was seen throughout. Photopoints and numerical methods both showed that *Chionochloa antarctica* tussock was eliminated or greatly reduced where goats and pigs occurred together, and where only pigs were present it was reduced slightly. Despite browsing by goats, woody vegetation has continued to replace the *Chionochloa* tussock grassland and occupy sites where tussock has been removed. *Poa lito rosa* tussock has further invaded a strip of dead *Hebe elliptica-Metrosideros umbellata* forest killed by goats and by exposure to the wind.

As the low-altitude *Chionochloa* tussock disappears, goats may move to unmodified tussock grassland at higher altitudes and so gain access to other parts of the island. Pigs, by rooting and browsing, will continue to reduce lowland *Chionochloa* in their range. Extermination of pigs and goats from the main Auckland Island should therefore be planned.

Keywords: Auckland Island; subantarctic; goats; Capra hircus; Bovidae; pigs; Sus scrofa; Suidae; Chionochloa antarctica; Gramineae; feral mammals; vegetation changes.

Introduction

The Auckland Islands (Fig. 1) are an uninhabited group at 166°00'E, 50°40'S in the New Zealand subantarctic, 400 km south of Stewart Island. Since the islands were discovered in 1806, goats, pigs, sheep, horses, cattle, dogs, cats, rabbits and mice have been introduced to various islands (Taylor, 1968, 1972) but sheep, horses and dogs have died out. There has been only one serious attempt to form a settlement (at Port Ross in 1849 at the northern end of the islands) but it lasted only three years. A brief description of the Port Ross area and its history is given by Taylor (1971) and Rudge and Campbell (1977). The Auckland Islands are now a nature reserve administered by the Department of Lands and Survey.

In summer 1972-73 we visited the islands to examine the distribution and status of feral goats *(Capra hircus),* and to study the vegetation both within and outside the area they occupied. In brief, we found that about 100 animals were living at the extreme north end of Auckland Island, mainly near the coast. Goats liberated at nine other sites had died. For a variety of reasons it seemed that the goats were neither likely to spread, nor increase in number.

During the same expedition feral pigs *(Sus scrofa)* were studied for much the same reasons as the goats (Challies, 1975). From that survey, and a review of the historical record, Challies concluded that the population had passed through .an "eruptive fluctuation" late last century and pigs were now distributed in low numbers throughout Auckland Island. Their impact on vegetation (and nesting sea birds) had previously been very destructive, but he concluded that pigs would now continue to exist in balance with an improverished flora.

During the 1972-73 expedition we measured and photographed the vegetation in areas occupied by pigs alone and by pigs and goats together. These sites were marked so that they could be relocated for long-term comparative studies. The siting of permanent plots was intended to cover the range of different plant communities within the study area, and to identify the effects of differing densities and combinations of pigs and goats. This report describes changes found in eight of those transects and photopoints during a re-examination between 2 and 10 April 1983, 10 years after they were first measured.

Methods

Figures 1 and 2 show the study sites established in 1973 around Port Ross, and those which were re-examined in 1983. The sizes of each of our plots and the measurements we made in 1972-73 have been published previously (Rudge and Campbell, 1975), and measurements made in 1983 are listed in Table 1. Copies of the 1973 photographs were used to locate the marker pegs and orient the transects precisely.

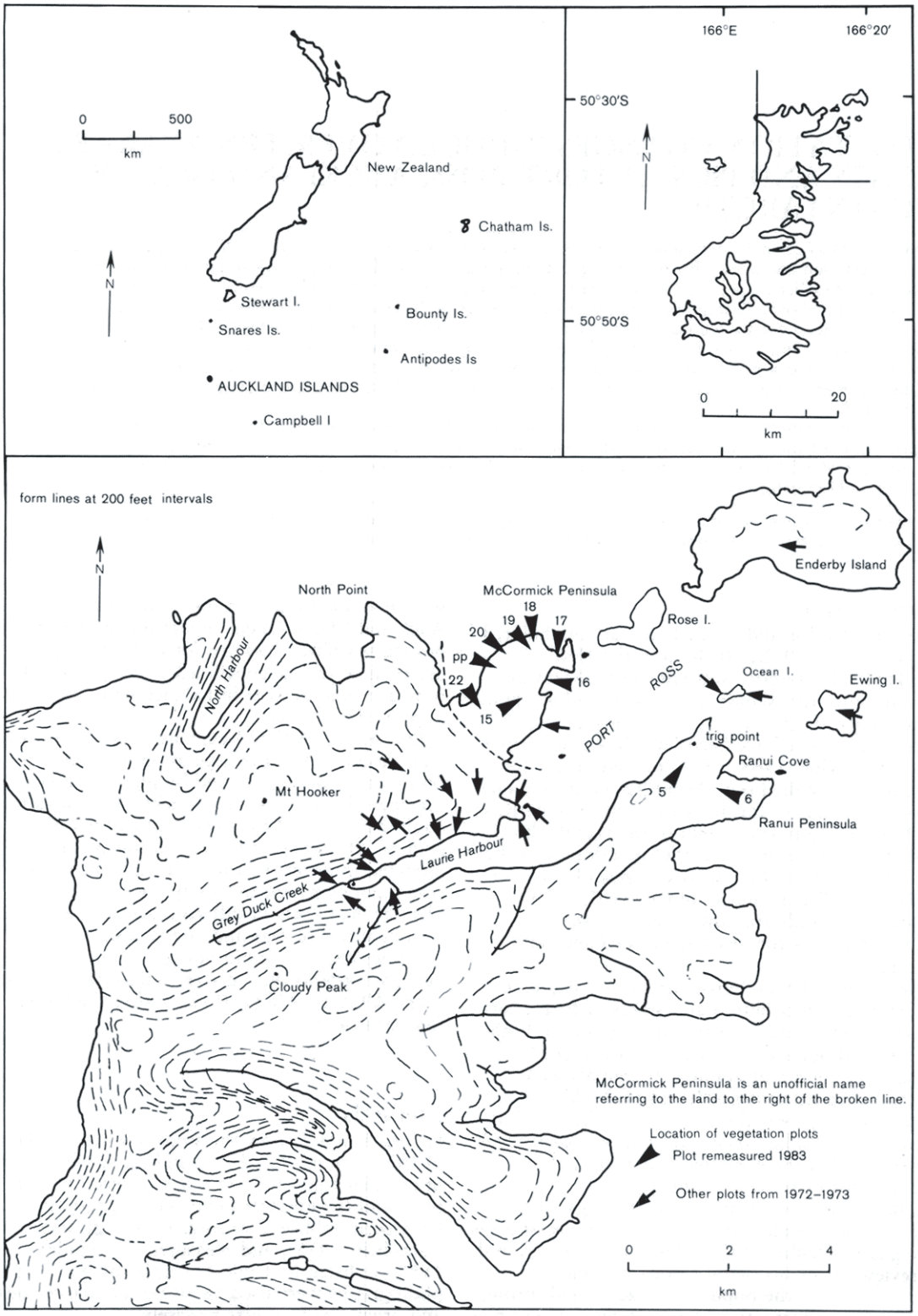

Figure 1: *Location of Auckland Islands. McCormick Peninsula is an unofficial name referring to the land east of the dotted line.*

Figure 2: *Panorama from the top of Deas Head showing the approximate location of all plots on McCormick Peninsula referred to* in *the text. April 1983.*

Table 1: *Sizes and types of permanent plots on Auckland Island remeasured in* 1983. *All sites were photographed; only those with* Chionochloa *in* 1973 *have been quantitatively analysed with a dot pattern.*

Plot number	Location	Size (m)	Vegetation	Measurement 1983
5	Near Ranui Lookout	2(5 x 0.5)	moorland	profile, belt, dot
6	Near Ranui Camp	30 x 1	*Chionochloa* grassland	profile, belt, dot
15	Near Deas Head	5x 0.5	moorland	profile, belt, dot
	Near Deas Head	l0 x 1	scrub edge	profile, belt, dot
18	McCormick Peninsula	20	*Poa litorosa* grassland	profile
19	McCormick Peninsula	2(5 x 0.5)	*Carex /Cassinia*	profile, belt
20	McCormick Peninsula	5 x 0.5	moorland / *Cassinia* Scrub	profile, belt, dot
22	Matheson Bay	30	*Poa litorosa* / *rata* transition	profile

Each of the eight sites was re-photographed, and the previous belt transects, line intercepts and profile drawings were repeated. Photocopies of the earlier field records were valuable in relocating sites, especially where sea-lions *(Neophoca hookeri)* had flattened the markers. If a site showed little change we annotated the photocopies rather than spend time on a complete resurvey. Drawings of belt transects from 1973 and 1983 were later quantitatively compared by placing a grid of dots over them and scoring the 'hits' on the vegetation represented.

We also took with us copies of photographs taken by the German scientific expedition which had spent five months at Port Ross while observing the transit of the planet Venus in 1874-75 (Godley, 1970). Some of these 'photopoints' were relocated and photographed to see what longer-term changes in the vegetation could be detected.

Goats and pigs were recorded as we (or they) moved through the study area, and we were able to scan Hooker Hills and McCormick Peninsula with binoculars. Our time ashore was too brief to repeat the 1972 surveys of North Harbour and Laurie Harbour.

Results

Goats

(i) Numbers and distribution

A minimum 52 goats in 12 distinct groups were counted. The number recorded in the corresponding areas 10 years earlier was 54 (Table 2). There was continual meeting and parting of these small groups in the 10 days that we watched them.

On the undercliff, which we dubbed "Goat Point" in 1973 and where a few goats were cut off from the rest of the population, there were only 4 animals (adult male, adult female, two juvenile males) whereas six were seen in 1973. A lone male was living on equally isolated ledges in the cove behind Pillar Rock. He was in good condition, but judging from the closely browsed and dead *Hebe elliptica* bushes he had been marooned there for some time.

Table 2: *Number of goats seen, and their locations in* 1973 *and* 1983. (1973 *data from Rudge and Campbell* (1977); **McCormick Peninsula shoreline not surveyed in* 1983).

Location	1983	1973
McCormick Peninsula	36 (7 groups)	37 (+ 13 on shoreline)
Goat Point/Pillar Rock undercliffs	5. (2 groups)	6
Nonh Point	>5 (1 group)	13
Hooker Hills	6 (2 groups)	0
Total minimum seen	52	54 (+ 13*)

Three goats were seen on Hooker Hills towards Cave Rock where the scrub zone gives way to grassland of the subantarctic tussock *Chionochloa antarctica* above about 300 m. No goats or their sign had been recorded as high as this in 1973 and no evidence of goats was found between Cave Rock and Mt Hooker in 1983 (M. Foggo, pers. comm.). None have been reported on Ranui Peninsula, southeast of Port Ross.

(ii) Habits

Groups of goats remained mostly in the open clearings and lanes, or moved through the scrub from one clearing to another. Two goats were encountered as they moved slowly through rata *(Metrosideros umbellata)* forest eating epicormic shoots from trees of *Pseudopanax simplex* and *Coprosma foetidissima,* and picking up freshly fallen leaves. Faecal pellets were rarely found in forest but were common and locally abundant in the open grassy areas.

On one occasion a group of goats were seen at close quarters eating leaves of *Chionochloa,* and freshly nipped leaf bases were found on young plants nearby. This was the first field observation that they (as well as pigs) ate *Chionochloa,* although we had identified this plant in faecal pellets in 1973.

Pigs

Wherever we went we saw pig sign (rooting or faeces), or occasionally the animals themselves. We watched one pig digging up *Carex appressa* rhizomes, and at Ranui DJC watched another from a distance of less than 2 m, while it rooted up a small *Chionochloa* tussock and ate the lower part of the tillers. Pigs had also pulled tillers from large standing tussocks to eat the sheath bases. Some faeces we collected contained only *Chionochloa* foliage or sheath bases. Browsing on *Chionochloa* is hard to detect because leaves have an abcission zone at the ligule which breaks cleanly when a leaf falls or when a living leaf is pulled.

Pig rooting formed hollows and trenches which filled with water in the open moorland. Sometimes, after pigs had grubbed around the roots of isolated rata shrubs in the open, the shrubs became surrounded by a water-filled moat.

Vegetation

The vegetation of the Port Ross area, including the study sites, has been described in more detail and mapped by Rudge and Campbell (1977). The view towards the west and north from Deas Head (Fig. 2) shows rata forest near the shoreline at the right of the photo, dense *Dracophyllum /ongifolium* var. *cockayneanum* scrub along the western margin of the forest, and 'lanes' of open herbaceous vegetation separated by scrub consisting mainly of rata, *Dracophyllum, Myrsine divaricata* and *Cassinia vauvilliersii*. The vegetation is shown in illustrations of some of the study sites.

(i) Sites on McCormick Peninsula

All sites on McCormick Peninsula (Figs. 1, 2) were in the area occupied by both goats and pigs.

Site 15 is open moorland bounded by scrub, part of the 'lane' system of scrub and moorland which ramifies over McCormick Peninsula. Figure 3 shows the general appearance of the site in 1973 and 1983. The herbaceous vegetation is shorter and more open in 1983 mainly because there is less *Chionochloa* and litter. The profile drawing of the open moorland section of the transect (Fig. 4), reveals that the small *Chionochloa* plants present in 1973 have all disappeared, and that pig rooting has removed a small rata shrub. The other small woody plants present in 1973 are still there and have grown by up to 100 mm in height. A *Myrsine divaricata* has become established at 3.5 m along the transect.

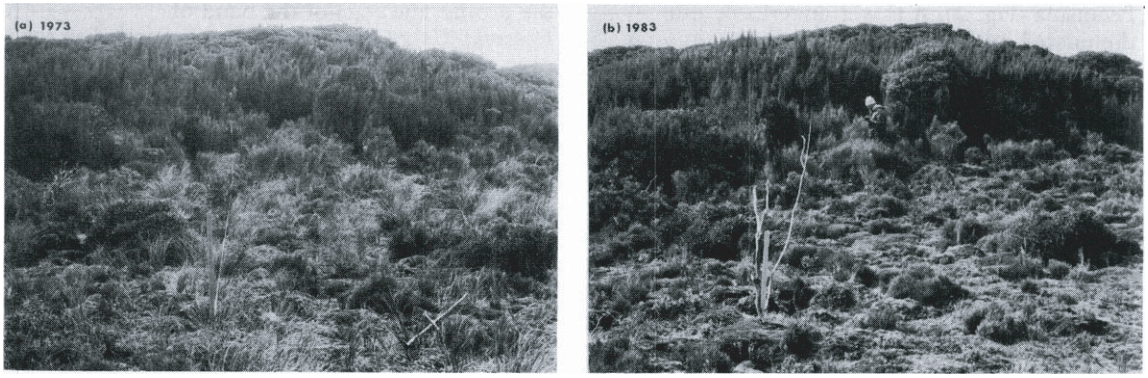

Figure 3: *Site 15, paired photographs, moorland transect. Chionochloa and litter have decreased, Oreobolus and pig rooting have increased. There has been only a slight increase in height of the shrubs.*

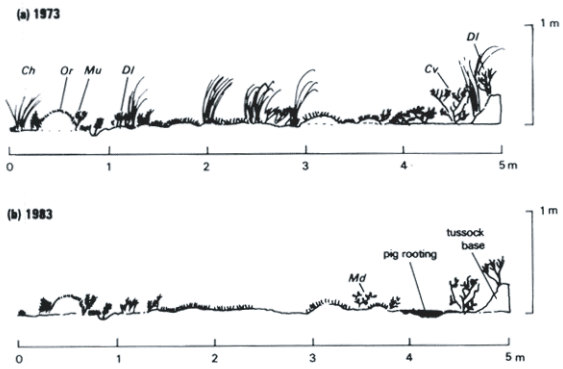

Figure 4: *Profile through open moorland, Site* 15. *Note' that all* Chionochloa *tillers have gone and a small rata has now been replaced by pig rooting*. Ch = Chionochloa antarctica, Or = Oreobolus pectinatus, Mu = Metrosideros umbellata, DI = Dracophyllum longifolium *var*. cockayneanum, Cv = Cassinia vauvilliersii *var*. vauvilliersii, Md = Myrsine divaricata.

The point intercept results for the belt transect (Table 3) show a decline in *Chionochloa* and a parallel reduction in its litter.

The woody plant cover values have generally remained the same or have increased slightly. *Oreobolus pectinatus,* the hummock-forming sedge, has shown largest increase in surface area, partly because it is no longer obscured by the taller tussock or covered by litter. This plant colonises bare peat and encroaches onto the peaty bases of dead tussocks.

Table 3: *Site 15*: *Percentage cover values from point intercepts on a 5m* x *0.5m transect drawing (1000 sample points) as recorded in surveys conducted in 1973 and 1983.*

	1973	1983
Metrosideros umbellata	3	3
Dracophyllum longifolium	14	18
Cassinia vauvilliersii	2	3
Cyathodes empetrifolia	2	3
Coprosma pumila	3	-
Scirpus aucklandicus	5	6
Oreobolus pectinatus	24	35
Chionochloa antarctica	8	2
Litter	25	16
Bare peat	7	7
Other	8	6

Site 18 runs back from the edge of the northern cliff through tussocks of *Poa litorosa* and *Carex appressa,* scattered ferns of *Polystichum vestitum,* and into a belt of shrubby *Cassinia*.

The only changes between the two surveys were a reduction in *Polystichum* and a slight advance of the *Cassinia* into the *Poa* zone. On both occasions the sward between the tussocks and fern was closely grazed. Seedling *Poa litorosa,* fine-leaved grasses (especially *Poa antipoda,* P. *breviglumis* and *Deschampsia chapmanii)* and herbs were components of this sward. The sides of the mature tussocks had distinct 'shoulders' caused by browsing and by animals rubbing past.

Site 19 slopes down from the cliff top at site 18 towards the main drainage of McCormick

Peninsula (Fig. 2). It is wet underfoot, and dominated by *Poa litorosa* and *Carex appressa* over a sedge-dominated sward with about 30% cover of moss. (Detailed composition figures are given in Table 8 of our 1977 report as "wet peaty turf near site 10"). At the bottom of the slope, *Cassinia* delimits the zone of continuous scrub. Table 4 shows that *Carex, Poa* and *Cassinia* have all increased but the amount of litter and pig rooting (= 'other') has decreased.

Table 4: *Site* 19: *Percentage cover values from poitit intercepts along a 10m* x *1m transect drawing (1000 sample points as recorded in surveys conducted in* 1973 *and* 1983. *In 1973* Carex *litter and pig rooting comprised the 'other' category, whereas in 1983 it was mainly pig rooting.*

	1973	1983
Cassinia vauvil/iersii	10	16
Carex appressa	7	15
Poa lito rosa	4	9
Sward	46	56
Other	33	4

In the profiles (Fig. 5) there are two differences betWeen 1973 and 1983. In the 0-5 m section of the profile *Scirpus aucklandicus* sward has increased at the expense of the previously sparse *Cassinia, Carex* and *Poa*. In the 15-20 m parr of the profile, the edge of the band of *CassinialCarex* is taller and has expanded to take over about half the area of sward that was present in 1973. Beyond the transect, around some sea-lion wallows, is a drier area that in 1973 looked like a golf green but which by 1983 was covered in *Cassinia* 1 m high.

At this site there is clearly an interplay of factors that include water table, browsing, exposure, pig rooting and sea-lion activity. Goats continue to use the area, and pig rooting (especially for *Carex)* is evident throughout, although bare ground exposed by pigs in 1973 had become covered in moss and *Scirpus* by 1983.

Site 20 runs norch to south from an exposed cliff which slopes down to the sea. It passes through dense *Poa litorosa* and *Carex appressa* on the cliff edge, across moorland on the ridge crest and into *rata-Dracophyllum* scrub on the lee side.

The *Poa* and scrub ends of the transect appeared to be virtually unchanged since 1973. Figure 6 shows the changes along the profile in the exposed moorland segment of the transect. Most of the wispy *Chionochloa* tillers present in 1973 have disappeared, and those that remain are smaller; *Oreobolus* has colonised bare peat; and a dead standing *Cassinia* bush has almost disappeared.

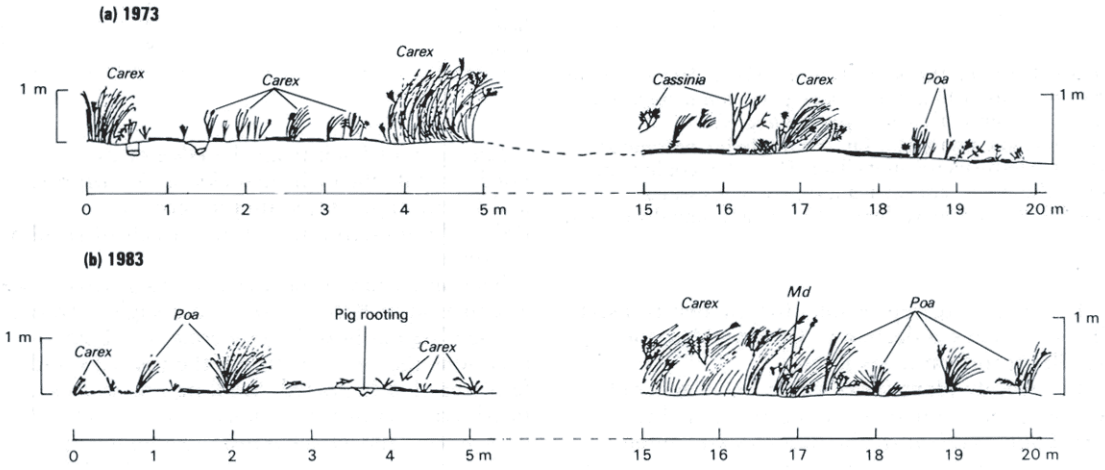

Figure 5: *Site* 19. *Transect profiles between 0-5 m and 15-20 m. In the 0-5 m section the tall* Carex *that was present in* 1983 *has been replaced with scattered small plants, and a* Poa litorosa *has grown at 2.0 m. In the 15-20 m section both the* Carex *and* Poa litorosa *have increased, and a small* Myrsine divaricata *has established at 17 m.*

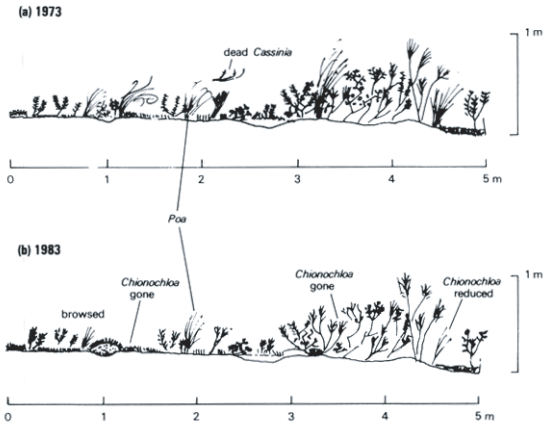

Figure 6: *Site 20, moorland at cliff top, McCormick Peninsula. Several* Chionochloa *tussocks have gone or have been reduced to a few scraggly tillers. Dead* Cassinia *branches and litter have gone. A large* Oreobolus *has colonised bare peat. Woody plants are 50-100 mm taller in* 1983.

Figure 13 shows that the cover contributed by *Chionochloa* at this site fell by 34% over the decade. The heights of the woody plants were Iittle changed. The plant cover on this site was already rather sparse in 1973, so the visual change is not as pronounced as for site 15 (Fig. 3).

Site 22 is on the western side of McCormick Peninsula, and runs from the cliff edge above Matheson Bay through *Poa litorosa* tussocks into dead rata which borders the edge of the rata forest. The rata at this site was interpreted in 1972/73 as dying back because of exposure to wind and salt spray. Remains of dead standing shrubs in 1972/73 showed that hardy *Hebe elliptica* had previously been growing on the windward side, protecting the rata from salt-laden storms. We deduced that browsing by goats had killed the *Hebe* (see comment above on the goat at Pillar Rock). In 1973 we saw a goat near site 22 standing with its front feet on a lower branch of a *Hebe* bush to reach the foliage. No *Hebe* seedlings and no living leaves had been recorded within the browse zone in 1973. Comparison of profile diagrams drawn in 1973 and 1983 (Fig. 7) shows that the canopy has continued to lose living and dead material since 1973 and the whole area is much more open (Fig. 8). *Poa litorosa* is colonising formerly wooded ground, and on the seaward side it is robust and vigorous.

(ii) Sites on Ranui Peninsula

The two sites on Ranui Peninsula are frequented by pigs but are outside the area occupied by goats.

Site 5 is located on the ridge that runs from

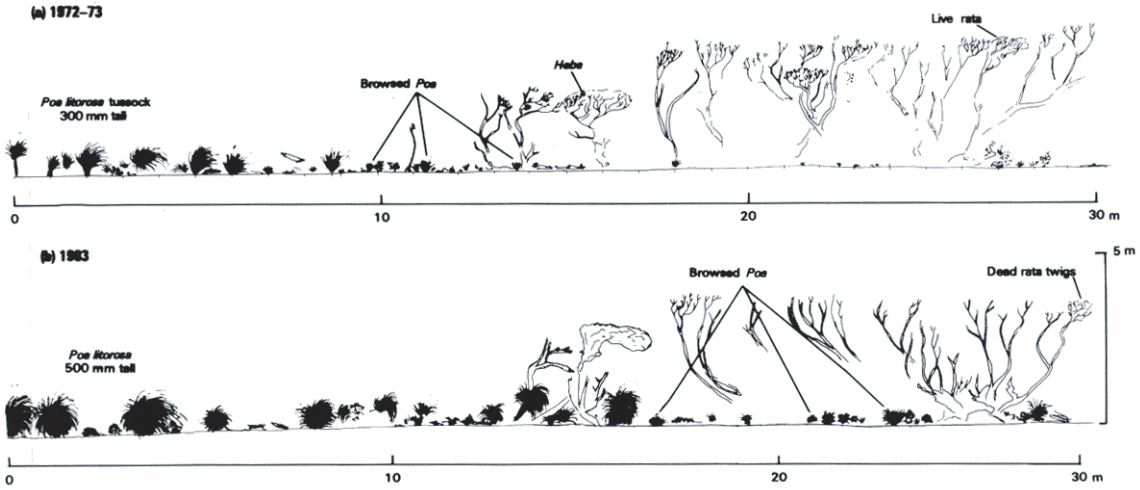

Figure 7: *Site* 22, *profile through* Poa litorosa *and dead* Hebe *into eroding rata forest. In 1983 the zone of young.* Poa litorosa *plants which were browsed, now extends further into the edge of the rata, and the previously browsed plants have grown taller.*

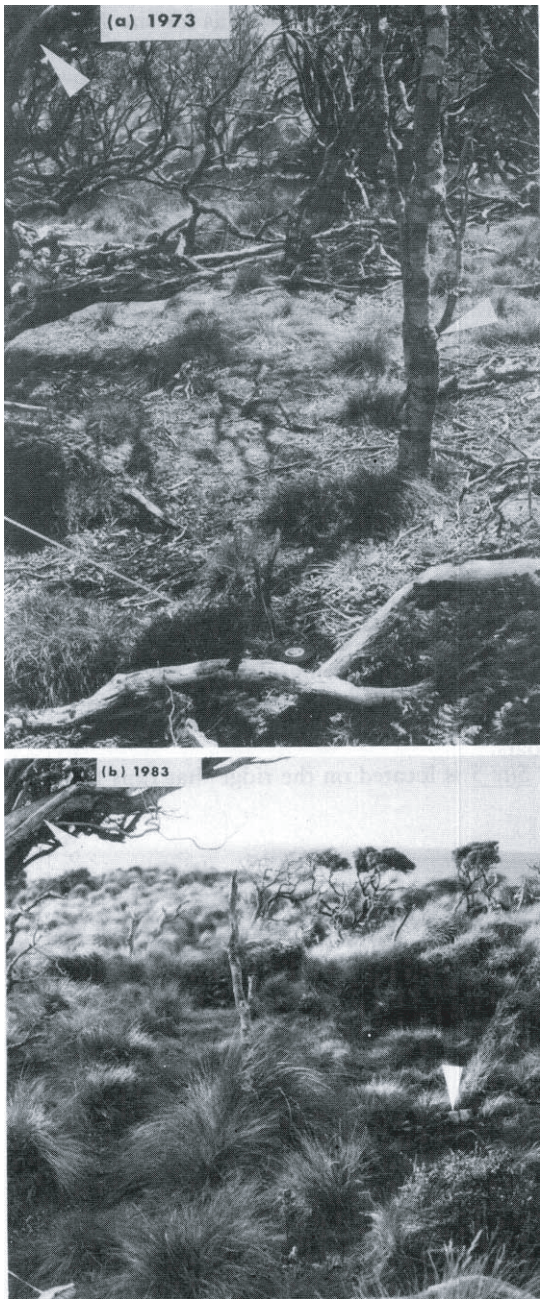

Figure 8: *Site* 22. *Matched photographs showing changes at the inland end of the* Poa litorosa - *rata forest transect, Matheson Bay. The markers indicate prominent trees present in 1973.*

the Ranui lookout towards Mt Eden. It runs from north to south through exposed level moorland and then dips into a more sheltered hollow filled with scrub and tussock. The site was selected because its topography, drainage and exposure are similar to site 20 in the goat range.

The paired photos (Fig. 9 a, b) and the profiles (Fig. 10) showed that the site had not changed perceptibly. Identical plants could be seen and they had scarcely grown during the decade. Moreover, point intercept analysis of the belt-transect map of the moorland and the scrub sections showed little change in the *Chionochloa* cover; on the moorland end of the transect the 1983 value was 92% of that in 1973, and in the more sheltered hollow at the south end it was 110%.

Site 6 is in a sheltered hollow near the creek that drains into Ranui Cove. It is topographically similar to site 15 in the goat range, and like it is nearly surrounded by patches of rata scrub up to 5 m. In contrast to site 15 it is filled with *Chionochloa* tussock. The general appearance in 1973 and 1983 is shown in Figure 11. Many tussocks were flowering (in marked contrast with McCormick Peninsula) but there were dead and pig-rooted ones in between them.

The profile diagrams (Fig. 12) show some gains and some losses of *Chionochloa,* which resulted in little overall quantitative change along the line. In contrast to any site on McCormick Peninsula, the taller tussocks were flowering (Fig. 11). Pig rooting and pig faeces (mainly composed of *Chionochloa* leaves or tiller sheaths) were prominent all over the site. The quantitative analysis of the transect drawings shows only 11 % drop in *Chionochloa* for this site. While we were resurveying the transect we observed that the main change was a reduction in the volume of larger tussocks, chiefly because pigs had removed tillers from the accessible sides of the tussock pedestals. Dead mature tussocks meant that fewer nearby tussocks arched over the profile line. The overall change which had occurred during the 10-year interval between our visits was that some of the large (and no doubt very old) tussocks had died, and some young plants had become established. At the scrub end of the profile (not shown in Fig. 12) there had been an increase in size and cover of woody plants but no appreciable incursion into the tussock. Only further long-term measurements will show whether the apparent loss of *Chionochloa* from this site is a continuing trend.

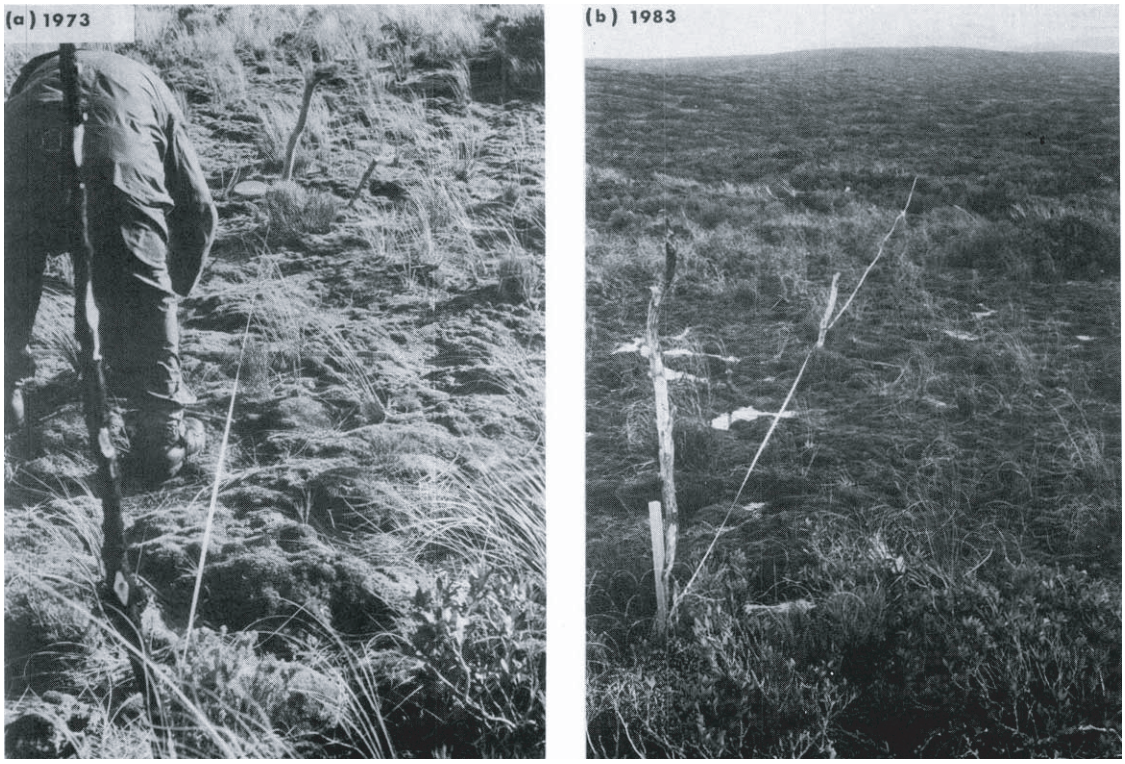

Figure 9: *Site* 5. *Matched photographs from the north end through open moor.*

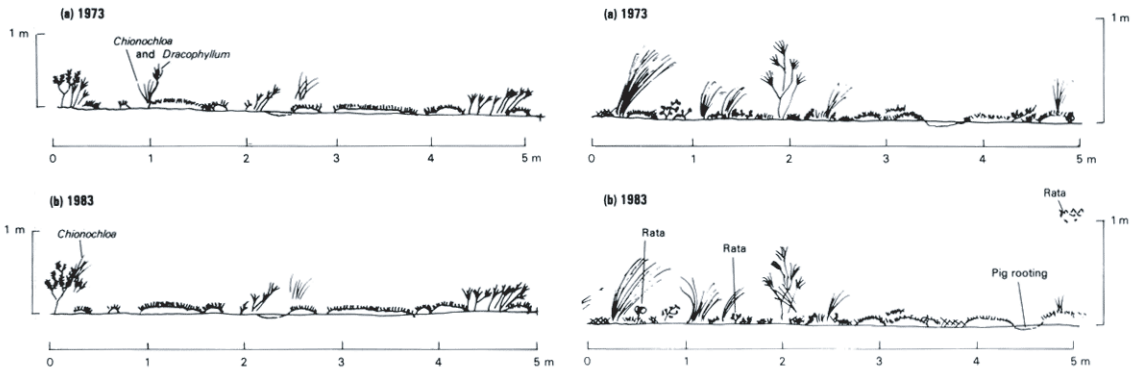

Figure 10: *Site* 5. *(left) Transect through exposed moorland. Very little change has occurred. The* Dracophyllum *at 0.3 m has grown by 200 mm but that at* 4.5 *m has remained the same.* A *small* Chionochloa *and* Dracophyllum *at* 1 *m has gone, and a nearby* Chionochloa *has grown a little to over-arch at 0.3 m. (right) Transect profile in a sheltered hollow. Little change has occurred.* A *tiny rata at* 1.5 *m is still there, and another has established at 0.6 m. Pig rooting has exposed peat at* 4.5 *m.* A *rata bush at* 5 *m has grown and now over-arches the transect. The* Chionochloa *tussocks are 100 mm taller and contribute most of the litter.*

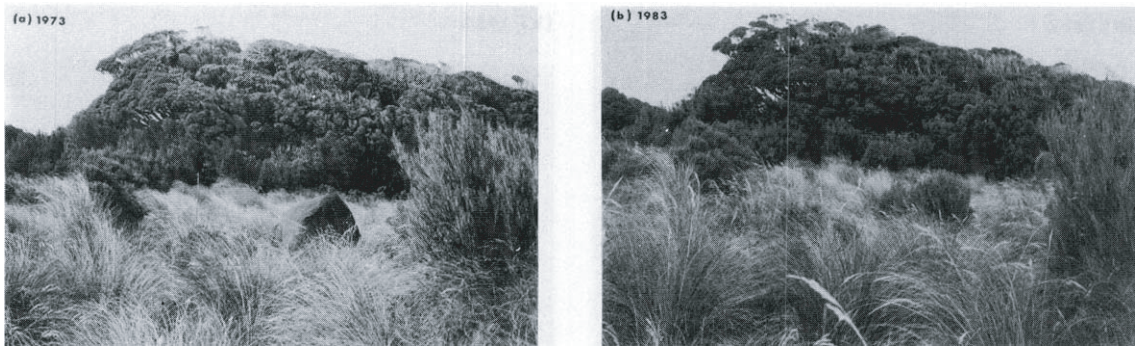

Figure 11: *Site* 6 *behind Ranui camp. Note that the tussock is flowering in both late December 1972 and April 1983. The object in the upper photograph is an emergence trap for insects.*

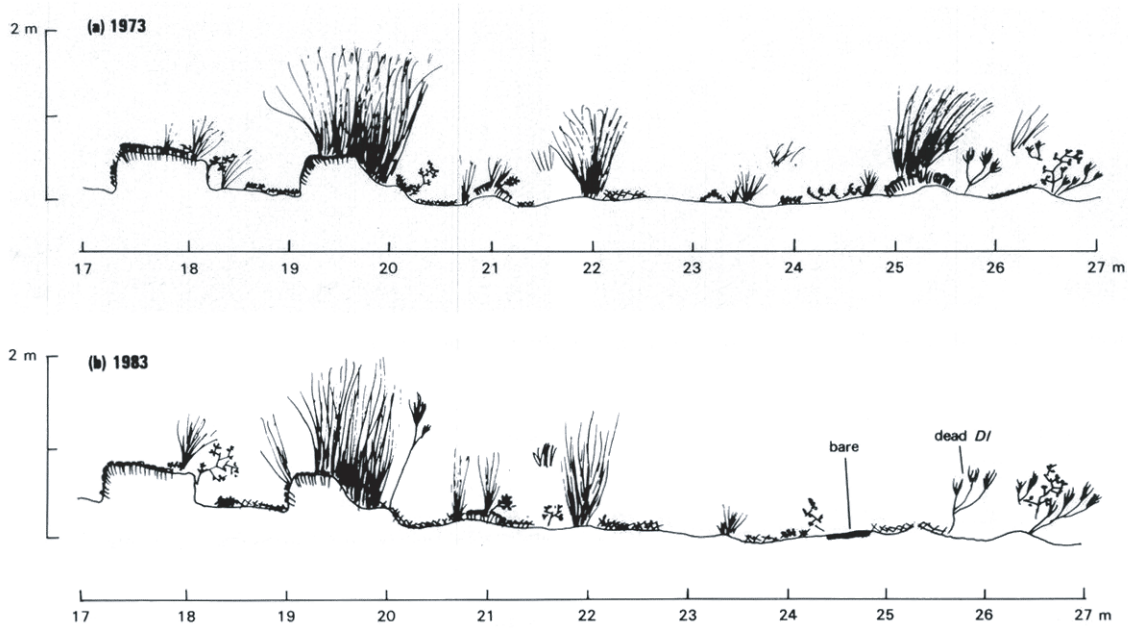

Figure 12: *Site* 6, *Profile of the transect in a sheltered hollow behind Ranui Camp.* Chionochloa *has been lost from* 17.5, 21.2, *and 25.5 m. Less* Chionochloa *is over-arching the profile because nearby tussocks have gone. New* Chionochloa *tillers have established at* 19 *m. A new* Dracophyllum *has established at 20 m and the one at 25.8 m has died. Bare peat now occurs instead of tussock at 25 m.*

Discussion

Past influences

Before we can interpret present day changes in the vegetation on the marked plots the longer-term background influences on the vegetation must also be considered. The two main ones for which there is any documentation have been modification by humans and by pigs, but until our 1975 report (Rudge and Campbell, 1975)

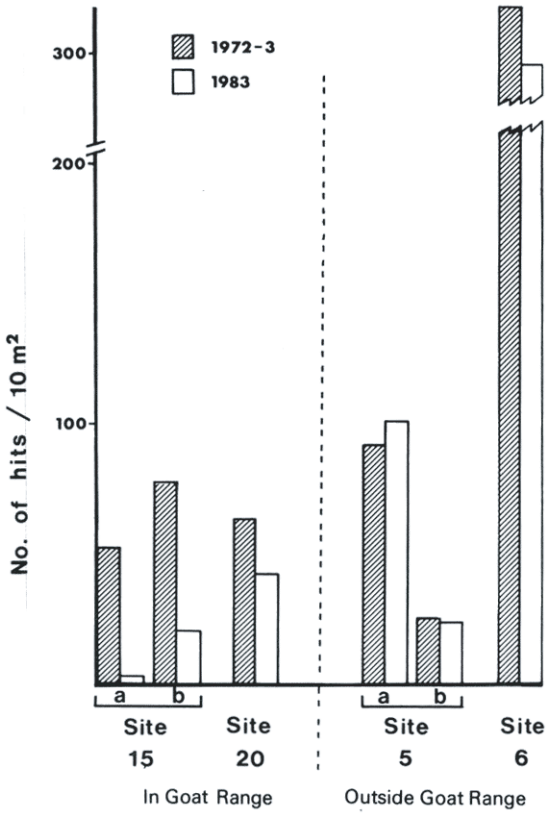

Figure 13: *Comparison of the cover values of* Chionochloa *in sites remeasured in 1983, all plots standardized to the same area. The decrease in the cover of* Chionochloa *in the sites frequented by goats is highly significant (p< .001). The difference in cover in sites frequented by pigs alone is not significant (p < 0.025) but* 88% *of the difference is due to the decrease of* Chionochloa *on plot* 6. *The absolute amount of* Chionochloa *present on plot* 6 *is much greater than for all other sites, and the decrease in cover is similar to that in the sites where goats are present.*

nothing had been recorded about the impact of goats. The observed changes in the amount of woody vegetation may be partly explained by ameliorating climates since the 1950s (Salinger, 1982; Meurk, 1977).

(i) Human modification

In our 1973 survey we found charcoal all across Ranui Peninsula, along the shores of Laurie Harbour, across McCormick Peninsula, and on the lower slopes of Hooker Hills (Rudge and Campbell, 1977: Fig. 4). Most of the fires were presumably lit during the brief period of settlement in the early 1850s. The photographs taken in 1874 during the German expedition suggest that the area west of Matheson Bay may also have been burnt. Hooker Hills may also have been burnt, but *Chionochloa* tussock would not leave much charcoal as evidence of it. *Chionochloa* and the resinous *Dracophyllum* would both have burned readily and carried a fire through the scrub. If the weather were dry enough for a fire to catch at all, the peat may have ignited and continued to burn intermittently for much longer.

This phase of modification extended from about the 1840s to, at least, the 1860s and perhaps longer, but since then regeneration has proceeded unhindered by man. Unfortunately, neither the German expedition's nor other early photographs provide much insight into the course of this recovery. The 1874 view across McCormick Peninsula to Deas Head shows dead standing rata over thickets of scrub, with flowering *Chionochloa* in the foreground. One problem in interpreting the German expedition's 'photographs is that salt-laden winds can produce canopy damage which on photos is difficult to distinguish from that produced by fires. The 1874 photograph of Deas Head (Fig. 14) shows extensive dead canopy along the seaward edges of the tree crowns, yet this face is still clothed in big rata trees and we saw no evidence there of secondary forest. In some plots (sites 15 and 5) we found that parts of the rata canopy that were present in the 1973 photos were either completely missing by 1983 or appeared rather like the 1874 photographs reproduced in Figures 14. Other sites on McCormick Peninsula also had dead wind-shorn rata, and we conclude that violent storms in the last decade have battered the vegetation from the west or northwest. Today, all across McCormick Peninsula there is evidence of a formerly well developed *Chionochloa* community: peaty bases and recently dead tussocks occur in the open lanes, and there are tussock bases under the scrub canopy bordering the lanes. This invasion of lowland tussock grassland by woody vegetation also occurs on Campbell Island (Meurk, 1977, 1982). Growth or regrowth of *Chionochloa* to maturity happened in the presence of pigs and, later, of goats on McCormick Peninsula. It suggests that there were not many goats there in the early stages of

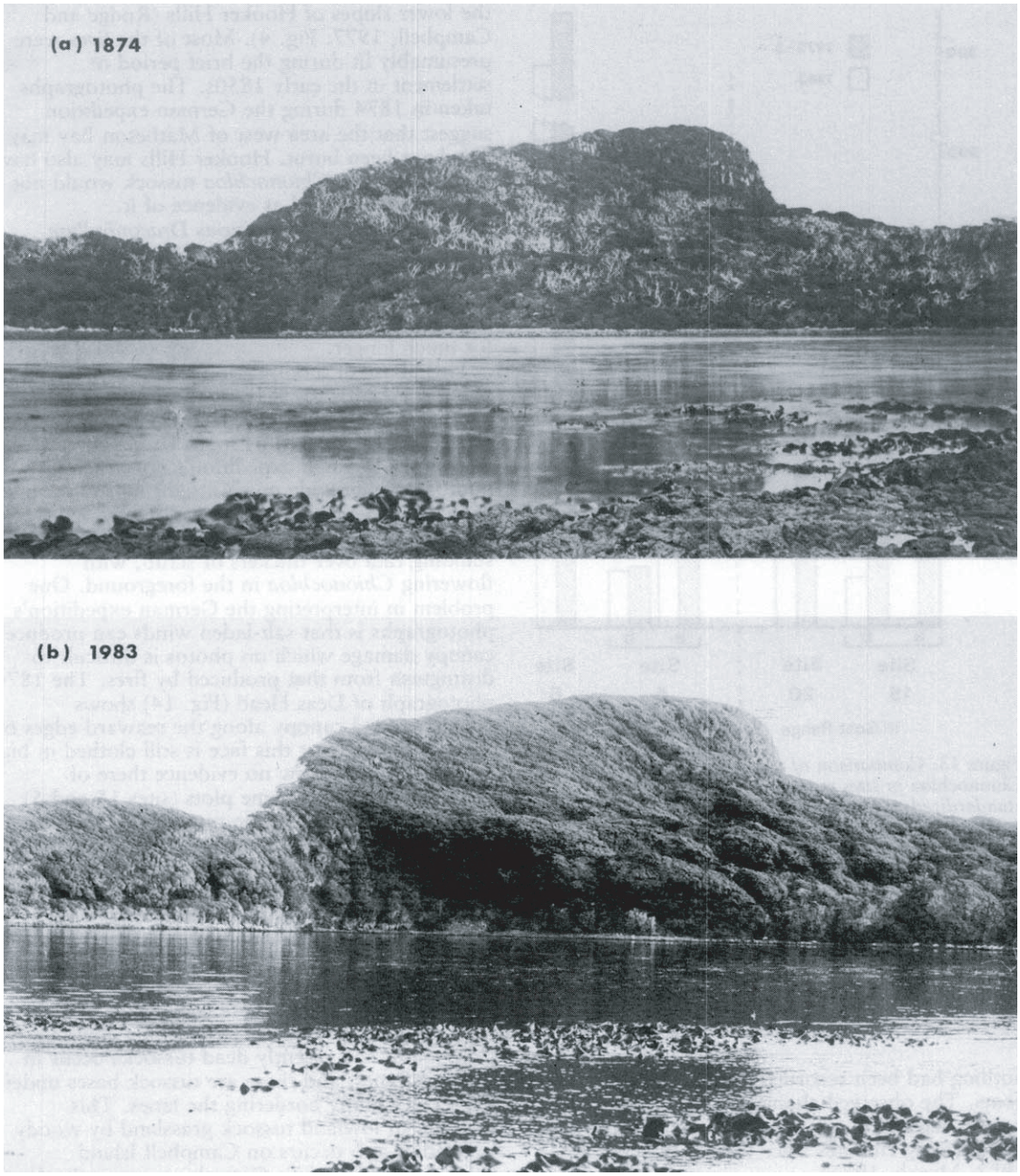

Figure 14: *Paired photographs taken across Lindley Cove towards Deas Head. Note the extensive die back of the rata crowns in* 1864-5, *compared with April 1983.*

regeneration, and this is confirmed by the lack of historical reference to goats over this period (Rudge and Campbell, 1977). It seems that *Chionochloa* was prominent in the regeneration that occurred after the fires, whether or not it was there initially. Mark (1965) has shown that narrow-leaved snowgrass *(Chionochloa rigida)* on the New Zealand mainland suffered no permanent damage from burning in the absence of browsing, and that burnt tussocks flowered profusely the second summer after burning. The shelter the tussock provided for seedlings of woody plants may have assisted the development of scrub that has since overwhelmed it.' Our plots show a big difference in the amount of *Chionochloa* on equivalent sites on the McCormick and Ranui sides of Port Ross. This difference will be discussed when the role of goats is considered below.

(ii) Pigs

Challies (1975) described the progress of the pig population since its beginnings in 1806, through an eruptive fluctuation, to the present stage of relatively low numbers distributed throughout the island. Pigs have removed an entire vegetation of large subantarctic herbs *(Anisotome* spp., *Bulbinella rossii, Pleurophyllum* spp., *Stilbocarpa polaris)* from all accessible sites, especially at low altitudes. Experienced observers (Ross, 1847; Hooker, 1847; Cockayne, 1909) documented this early depletion. As the other large-leaved herbs were eliminated, *Bulbinella rossii* roots became a favourite food (Waite, 1909). It is quite understandable that as favoured, accessible foods declined the pigs would turn to other sources. We watched pigs rooting up tussocks of *Carex* and *Chionochloa,* and pig rooting can be seen in all habitats including the open moorland. On Ranui Peninsula especially, *Chionochloa* is prominent in their faeces. Challies (1975) concluded that the *Chinonochloa* tussock and certain other vegetation may not have been modified much by pigs. Nevertheless, Challies found that all eight pigs shot in coastal sites had eaten grass, and 19% by dry weight of stomach contents from these pigs was grass. The grass was not identified to species, so we do not know how much was *Chinonochloa*. Rudge (1976) analysed 13 faeces collected at low altitudes in 1972-73, and found that tussock grasses and fine-leaved grasses occurred in all faeces: "In five, virtually the whole faecal mass was a ball of coarse chaff with pieces of lamina up to 20 cm long. In the remainder, the grass remains were basal parts of tussocks 2-3 cm long."

In 1983 M. Foggo (pers. comm.) reported that, on the tops of Hooker Hills, pigs have now turned their attention to *Chionochloa* and are digging up the tussocks and eating the roots.

It is clear that pigs have been making use of *Chionochloa* at least during the 10-year period that our plots have been measured. Considering the amount of *Chionochloa* available on McCormick Peninsula in 1972-73, and that pigs pull the tillers out completely, pigs alone may have been able to bring about much of the observed decline. There is no doubt that pigs and goats together will completely eliminate *Chionochloa* from low altitudes.

(iii) Goats

Details of the goats were first documented in our 1973 survey. Goats died out in eight of the 10 liberation points on the Auckland Islands, and those on Ocean Island were shot during World War II. The first certain mainland record was at Port Ross in 1891. We have found no historical comments on either the numbers or habits of this population. Apparently it never went through an explosive phase as the pigs did, and does not seem to be in such a phase at present. The tussock and woody vegetation on McCormick Peninsula recovered after the fires despite the goats. Moreover, large areas of tussock were widespread across McCormick Peninsula until recent times. It would be difficult to date dead standing tussock bases, but even allowing 30 years for them to decay, the influence of goats has mostly been that of steady attrition rather than rapid catastrophe, and it has not prevented the return of woody vegetation. One exception to this may be found in the rata forest on the west-facing slopes above Matheson Bay (site 22). In 1973 there was obvious recession of woody vegetation at this site, the only evidence we found of a decline in a woody community. A photograph taken of this area during the German expedition in 1874 is, unfortunately, not clear enough to show exactly what was growing there then, but the main cover does seem to have been *Hebe* with *Poa litorosa*. Certainly this whole shore has appropriate site conditions for the typical shoreline sequence of *Poa litorosa* to *Hebe elliptica* to rata back from the exposed cliff. We may have charted the loss of the last remnant of a community that wind and goats together have been destroying slowly for most of the century. Even if goats are now removed, the wind will still

beat back the margin of the forest, until plants such *Hebe* that tolerate salt winds can again establish on the seaward side of the rata.

Recent changes in vegetation

The conclusions drawn from the surveys of goats and pigs in 1972 were unavoidably speculative because there were few other measurements against which to compare the observations. The 10-year period that has elapsed since our plots were first measured allows us to test some of those conclusions and assess the rate and direction of change more precisely.

(i) Gains

As we predicted, woody vegetation slowly continues to recolonise those areas modified by fire last century. This trend appears to be widespread in the subantarctic as a response to warmer climates (Meurk, 1977). At site 15, which is in a 'lane', the margin of *Metrosideros* and *Dracophyllum* has continued to advance into the open moorland; at site 19 *Cassinia* bushes have advanced up a seepage slope which previously was covered by sedge swards and *Carex,* and have also obliterated open swards nearby. Elsewhere our profiles and belts showed remarkably little change. At sites Sa and 5b (Ranui) and 20 (McCormick) the 1973 and 1983 profiles were almost indistinguishable. Not only have no new plants established, but even the existing plants had scarcely grown in the 10 years. Similar slow growth rates were recorded by Meurk (1982) for shrubs on Campbell Island.

(ii) Losses

The loss of *Hebe* and then rata at site 22 is a possible long-term change, but the alteration of the edge of the rata forest over the last 10 years has been dramatic. Standing live trees have fallen since 1973 to leave an open site being colonised by *Poa lito rosa* (Fig. 8). Eventually this receding edge of rata forest will reach a new equilibrium where M *yrsine, Dracophyllum* and *Poa* can together form a new wind-sheer profile, but *Hebe elliptica* will not be part of it while goats remain.

The most conspicuous change revealed by our plots and photopoints is the loss of *Chionochloa* both within and to a lesser extent outside the goat range (Figs. 4, 6, 13). In 1973 there was little difference in the absolute quantity of *Chionochloa* on Ranui and McCormick Peninsulas (Fig. 13), except for the sheltered *Chionochloa-filled* hollow at site 6 (Ranui). In 1972-73 the similarity in absolute amounts of *Chinionochloa* between McCormick Peninsula (sites 15 and 20) and Ranui (at sites 5a and b) rather misled us as to the true effect of goats on *Chionochloa,* especially as the analysis of faecal pellets showed that goats were eating only small amounts (the total for tussock grasses *Poa* and *Chinonochloa* was 2.1 %). By 1983 *Chionochloa* had decreased overall in both areas, but much more in the sites used by goats. If, in 1973, we had calculated the ratio of living to dead *Chionochloa* in our 1973 plots on either side of Grey Duck Creek (the southwestern limit to goat range), we might have been able to predict the loss of *Chionochloa*. On the north bank (goat range) in 1973 it was 30:70 living to dead, and on the south bank (no goats) it was 95:5 living to dead.

If a sparse population of goats at the extreme edge of their range was exerting such an influence, then the main population on McCormick Peninsula should be having much more effect, as we now find. Within the range of goats *Chionochloa* has virtually disappeared from all plots, there is no evidence of juveniles having established, and no flowering *Chionochloa* was seen anywhere on McCormick Peninsula in 1983. In contrast, flowering was obvious at Ranui Cove (Fig. llb). Small amounts of *Chionochloa* were present in goat faeces examined in 1973 and although the absolute amount eaten must have been insignificant relative to fine-leaved grasses and shrubs, it has been enough to eliminate most of the remaining plants and prevent new ones from establishing. Pigs have also played a part in this decline. On McCormick Peninsula goats compete with pigs for fine grasses and this may force any pigs that live there to depend more on *Chionochloa*. Thus, goats clean off the interest, pigs attack the principal, and loss of *Chionochloa* is inevitable.

Uprooted tussocks were seen throughout the range of pigs. In the limited area we examined near Ranui, rooting and tearing was common, especially near site 6, and the transect at site 6 revealed a downward trend from 1973. The transect failed to reveal that much of the intercept volume was moribund and that these tussocks are likely to die back to stumps in the near future. We believe that when this happens the whole water balance of the site could be affected, both through loss of sponge and interception capacity above ground, and because of reduced transpiration. This could perhaps explain why *Oreobolus* moorland usually establishes after the loss of *Chionochloa* tussock.

Population trends

Pigs are still widely distributed, probably in about the same low numbers as recorded by Challies in 1973. The goat population is the same, at least on McCormick Peninsula and areas visible from it. We could not check the extremes of the range but reports from other workers during this visit and over the last five years suggest that the range has not increased. In 1973 we concluded that goat movement would be prevented by the dense scrub, the limited good at higher altitudes, and the physical barrier of Grey Duck Creek (Fig. 1). However, we saw goats higher on Hooker Hills than in 1973, in the zone where scrub gives way to continuous *Chionochloa* tussock. This may mean that they can, after all, move round the catchment of Grey Duck Creek via the upper tussock grassland and colonise the eastern coast. The shelter, as well as the food provided by a relatively intact tussock community may assist their dispersal southwards. Nonetheless, the upland tussock grassland is both wet and exposed, and goats do not generally thrive in wet and. windy conditions.

The future

We are still convinced that rata forest, and scrub communities dominated by rata, *Cassinia, Dracophyllum* and *Myrsine,* will survive and increase despite both goats and pigs. Much of the young rata forest has an open understorey, not because of browsing but because of deep shade in the regenerating stands and because of the traffic of sea-lions. When a canopy gap develops, species palatable to goats, such as *Pseudopanax* and *Coprosma,* are still able to survive on logs or when shielded by unpalatable *Dracophyllum* and *Myrsine*. The scrub communities bordering the moorland 'lanes' will continue to expand, albeit more slowly, in the presence of goats and pigs. Whether this trend would be occurring if the *Chionochloa* tussocks were tall and vigorous is open to question. We may be documenting an increase in scrub which is partly a consequence of the decline of the tussock grassland brought about by grazing, and partly by long-term trends in climate. Certainly, *Chionochloa* woody vegetation is still slowly increasing in all but the most exposed sites.

It is now clear that goats and pigs together will eliminate lowland *Chionochloa* grassland on McCormick Peninsula, and possibly that pigs alone will reduce (and perhaps eliminate) lowland *Chionochloa* from Ranui and elsewhere. In lowland sites woody vegetation is superseding *Chionochloa* tussock grassland perhaps as the lanes dry out in response to warmer climates. Nevertheless *Chionochloa* tussock grassland is still the dominant lowland vegetation in appropriate sites, but in the goat range many of these sites are now converted to open moorland dominated by *Oreobolus*. The *Oreobolus* has frequently colonised pig-rooted ground, or sites previously occupied by tussocks. The compact cushions appear to be effective in preventing other plants from establishing for several years. For goats this means that one food supply disappears.

Other coastal sites are being covered by *Poa litorosa*. Goats browse a little on adult *Poa litorosa* tussocks and have, by their grazing, sustained the swards of fine grasses (and cropped *Poa litorosa* turf) that provides their staple food source. Pigs compete with them for food at low altitudes (Challies reported 19% of grass in stomachs of pigs shot in coastal sites). However, there are extensive fields of *Chionochloa* above 300 m on Hooker Hills, which may induce the goats to explore higher than they have in the past. We have now seen some up on the edge of the upper altitude grassland.

Thus, although the numbers of goats have not increased and put pressure on the edges of the range, the loss of *Chionochloa* as a food resource on McCormick Peninsula may do it instead. Although the probability of this is only slightly greater than in 1973, the consequences are now much clearer than they were then. Even if goats move into the tussock above the area where we saw them on Hooker Hills, they would still have to travel some 10.5 km to get to Cloudy Peak, or to the more sheltered head of Chambres Inlet. We did not visit North Harbour, and visits to Chambres Inlet and the high country behind are very infrequent. If goats from North Harbour moved the 8 km via the upper tussock across the head of Grey Duck Creek, or those from Hooker Hills shifted southwards, it could well be several years before the increase in range was discovered.

It would be easy to eliminate the goat population and remove any possibility of spread to the south and east of Port Ross. On the peninsula itself, this would be of great benefit to *Hebe elliptica;* there could perhaps be an increase in *Chionochloa,* but there would be no change in the status of the large endemic herbs. We consider a combined operation should be attempted to control goats and pigs together. This would allow

whole communities to recover all around Port Ross. Over a 10-year period after sheep had been excluded from half of Campbell Island, Meurk (1982) found that *Chionochloa* had increased forty-fold. On the steep cliffs near Deas Head and Pillar Rock there are still many endemic herbs which are able to provide seed sources, and the experience on Campbell Island suggests a rapid and dramatic response (Meurk, 1982). Control of goats, but not pigs, would not achieve the recovery of the endemic herbs shown on Campbell where sheep were removed (Dilks and Wilson, 1979). Moreover, the removal of pigs may encourage albatrosses to nest again on Auckland Island. In 1983 we saw no sign of either the royal albatross *(Diomedea epomophora)* or its nest which, in 1973, was near site 20, nor any sign of the old nest bases that were evident around the nest occupied in 1973.

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