A COMPARISON OF THE BIOLOGY AND IMPACT OF FERAL GOATS (Capra hircus L.) ON SUBTROPICAL AND SUBANTARCTIC ISLANDS.

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ABSTRACT

Three populations on islands in the New Zealand region illustrate why feral goats are pests in many parts of the world in a variety of habitats. On subtropical Macauley Island goats reduced a burnt forest to grassland, and reached a density of 10/ha. About 22 percent of females bred twice each year. On nearby Raoul Island, goat density was 1/ha. The forest canopy was intact but regeneration was suppressed. Field and autopsy observations in 1972 indicated that if goat density were reduced, vegetation would recover and productivity would rise. By 1981-83, productivity had indeed risen from between 83 and 94 kids/100 females/year to 170 kids/100 females/year; and 23 percent of females bred twice each year compared with 1.5 percent in 1972. On subantarctic Auckland Island population density was 0.05/ha. Observations in 1973 suggested that the population was at the extreme of its environmental tolerance, numerically static, restricted in range and having little effect on the vegetation. By 1983, measured plots and photopoints showed that woody vegetation could slowly increase despite goats; but that lowland tussock grass and some localized palatable trees could be eliminated. There are sound biological reasons why goats are everywhere hard to exterminate. It seems that there are very few places where they can be tolerated without changing the vegetation. Control operations must be planned so as to minimize compensatory responses in goat productivity through increased food resources.

INTRODUCTION

Goats are one of the most widespread of domesticated animals (Rudge 1984a). They are found on all continents and many islands, amongst large and small human communities, and throughout all levels of the economic spectrum. They are small enough to be easily managed either individually or in groups, and eat a wide range of food of varying nutritional content, to produce milk, meat, and hides. Over a wide range of climatic conditions, they remain healthy and prolific. For centuries these characteristics have made goats valuable, not only as conventional stock animals, but also to supply fresh meat on sailing ships, and subsequently as the initial livestock of colonists in distant lands.

Because goats were such good travellers, foragers and general purpose livestock, they were commonly liberated in remote places, such as islands, to provide meat for shipwrecked castaways. Many such small transplants have since prospered to become large free-living populations.

The resilience and adaptability that were high among the merits of goats have now made pests of them in many places and particularly on islands. The classical example is the deforestation of the island of St. Helena (Darwin 1845), but their impact has also been tremendous in the Galapagos archipelago (Lewin 1978, Perry 1969), Hawaii (Yocom 1967, Scowcroft and Giffin 1983), New Zealand (Howard 1965), and in the desertified areas of the Mediterranean and Africa (Furon 1958).

New Zealand has never had native browsing mammals in its fauna. Many species of the introduced mammals are now pests (Wodzicki 1950, Gibb and Flux 1973) and the goat is prominent among them. For about 40 years vigorous control campaigns have been conducted with varying degrees of success. This has been done pre-eminently to protect native vegetation for its own sake, the native animals depending on that vegetation, and catchments susceptible to erosion. A variety of control methods has been used (Parkes 1984a), but despite all this effort, the distribution of goats on the mainland islands of New Zealand is still much the same as in the 1930's, although densities are now generally much lower (Figure 1).

On the smaller offshore and outlying islands the situation is a little different. Thirteen island populations have been exterminated, and only seven now remain. Islands are particularly valuable in the conservation strategy for New Zealand. Many have a high level of local endemism and others are used to liberate endangered species if there are no significant pests present.

A new consideration in conservation philosophy has arisen recently in a plea for nations to consider the contribution they can make to the genetic conservation of livestock (U.N. Food and Agriculture Organization 1975, Bowman 1981). Some of New Zealand's feral livestock species, such as sheep, provide opportunities to contribute to this cause (Rudge 1982, 1983), but the reputation of goats would seem to rule them out immediately. Now that so many populations have been exterminated, there may be some among the rest that are candidates for preservation. This paper compares three populations to illustrate some of the more obvious and more subtle effects of goats that must enter into such evaluations. Two cases come from the subtropical Kermadec Islands, and one from the subantarctic Auckland Islands.

THE KERMADEC ISLAND POPULATIONS

There are two main islands in the scattered Kermadec group, Macauley and Raoul (Figure 1). Both are volcanic and Raoul is still active. Macauley is the smaller of the two and is about 320 ha in extent, 2 km by 1.6 km, and rising to 213 m a.s.l. When it was discovered in 1788 it was described as covered in forest dominated by Kermadec ngaio (Myoporum obscurum), with deep rich litter layers and abundant bird droppings (Bowes 1787-79). At some unknown dates after that the vegetation was burnt and some goats were liberated. In 1827 it was described from a distance as being covered in rank grass and without a single tree (D'Urville 1832). In 1836 the whaling captain

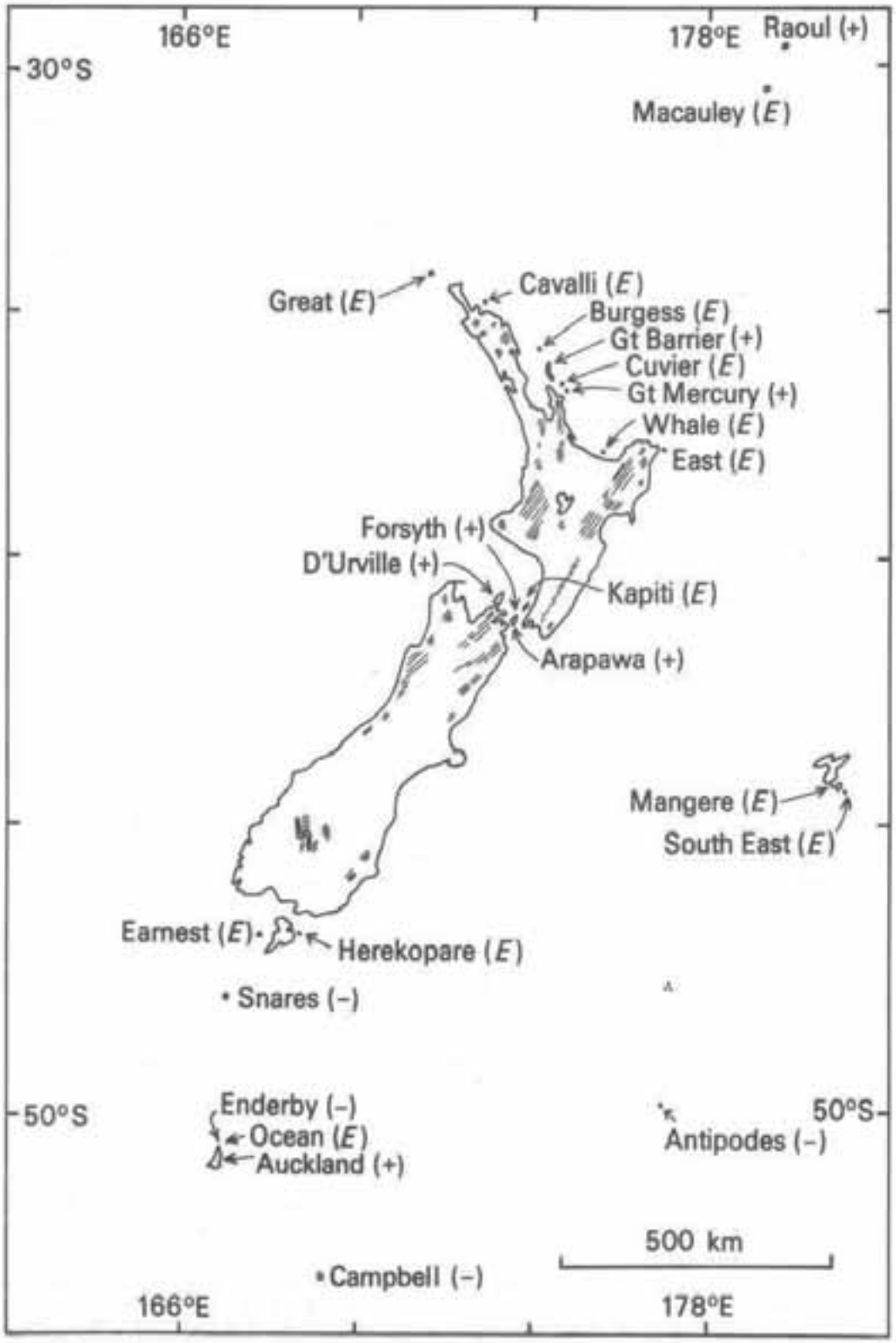

Figure 1. Distribution of feral goats in New Zealand in 1984. Mainland populations hatched; island populations present (+), died out naturally (-) or exterminated (E).

W.B. Rhodes landed and recorded a few stunted trees, herbage, and many goats (Rhodes in Straubel 1954). By 1966 the island was still entirely covered in herbaceous vegetation and the few remaining ngaio trees were confined to inaccessible cliffs (Sykes 1969). The density of goats was 10/ha, which as a visual comparison is about the stocking level of sheep on many New Zealand hill country farms. Despite this density, 22 percent of females were breeding twice each year, as indicated by simultaneous pregnancy and lactation. Of the kids, 33 percent died before birth but overall recruitment was 170 kids/100 females/year (Williams and Rudge 1969). This island represents the 'conventional' case of feral goats living at high density in a deforested habitat that had been altered initially by man. In this instance almost all of the 3200 animals were eliminated in a single operation in 1966 and the remaining 18 in 1970 (Sykes 1977).

Raoul Island was discovered by Europeans in 1793. It was uninhabited, and there is no sign that it ever had a permanent Polynesian population. It covers just under 3000 ha and rises to 518 m on the crater rim. Although volcanic activity has devastated the island from time to time, the predominant vegetation has probably been forest for the last 2000 years (Sykes 1969). Two main types of forest are recognized, both dominated mostly by Kermadec pohutukawa (Metrosideros kermadecensis). Evidence of transient Polynesian occupation has been found and here were several attempts at European settlement in the 19th century (see Sykes 1977). These intrusions left a legacy of adventive plants, several of which have become pests (Devine 1977, Sykes 1969). Goats and pigs were introduced some time before 1836 (Rhodes in Straubel 1954). In contrast to Macauley Island, they made their impact on an essentially pristine forest vegetation. The pigs were never very numerous and died out about 1964 (Sykes 1977). Externally the island still presents a lush forested appearance which belies the influence of the goats within it. Sykes (1969) summarizes the comments of botanists since Oliver (1910) on the destructive impact of the goats and the need to control them. Many formerly prominent plants had, by 1966, become restricted to cliffs and the vicinity of the Meterological Station (Sykes 1977). Few or no young plants of the main canopy tree, pohutukawa, were seen anywhere in 1966, and undergrowth was generally sparse or severely cropped (Sykes 1969).

Since 1933 there had been many sporadic attempts at goat control (sometimes encouraged by bounty payments to the meteorological staff) but serious work did not begin until 1972 (Parkes 1984a). By then the population was estimated at about 3000 (Sykes 1969), a density of 1/ha. The population has been reduced slowly since then until it is now on the verge of extinction (Parkes 1984a). Some characteristics of the population and its performance were examined in 1972 autopsy samples (Rudge and Clark 1978). This showed that in the parts of the island (such as near the Station), where density had been reduced by sporadic hunting, the animals grew faster as kids, and were larger and heavier age for age than elsewhere on the island. These differences in condition reflected the greater food supply from the recuperating vegetation. In contrast to Macauley, only 1.5 percent of females on Raoul bred more than once each year, and overall productivity for the island was between 83 and 94 kids/100 females/year. Goats on the New Zealand mainland showed greater productivity than this with 26 percent of females breeding twice each year, and 25 percent of pregnancies producing twins (Rudge 1969). In light of this it was predicted that as the population was reduced on Raoul there would be a rapid increase in understorey vegetation (food) and greater productivity among

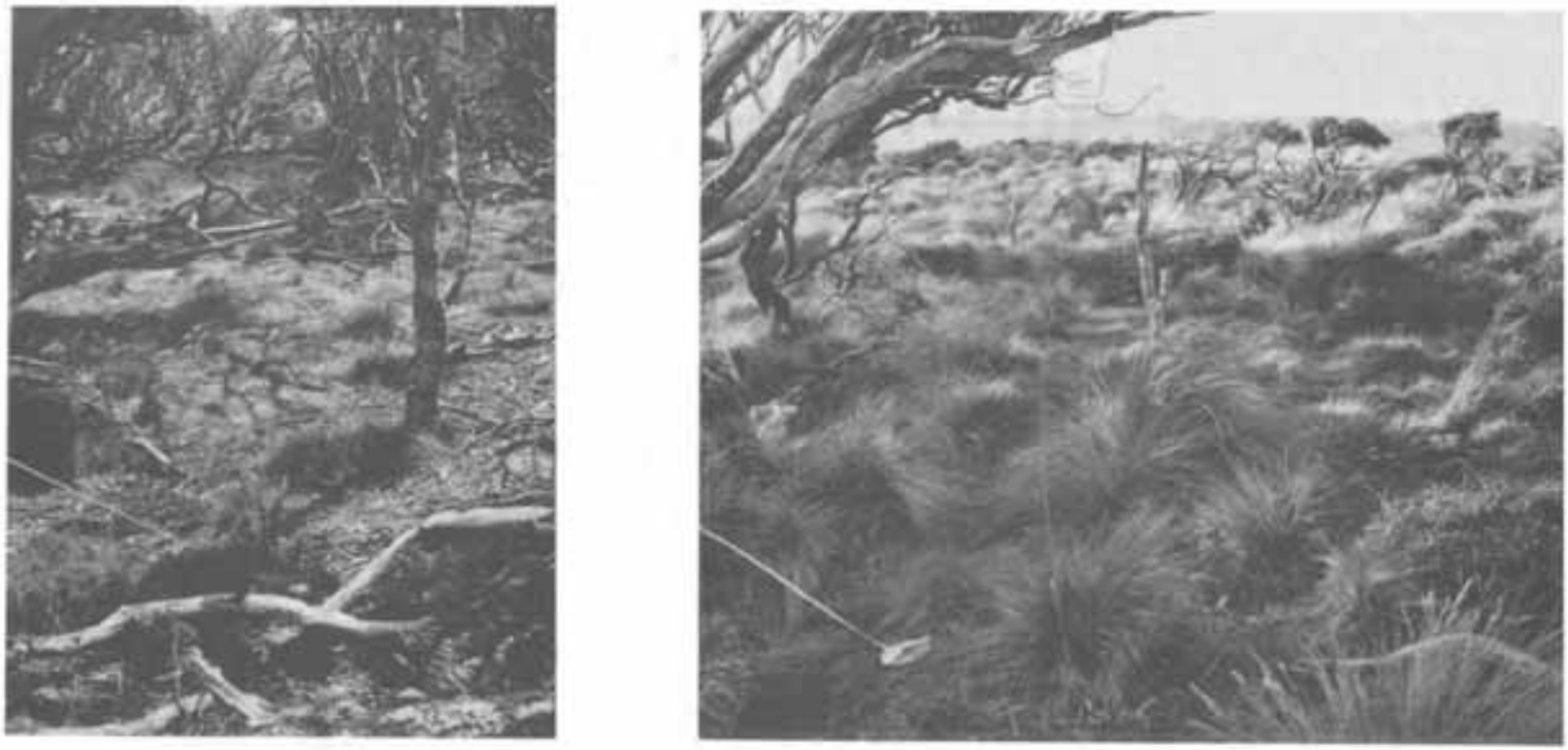

Figure 2. Loss of Hebe elliptica forest on Auckland Island and invasion by Poa litorosa tussock. Left 1973, right 1983.

seedlings of woody species which then overwhelmed it. This tussock had been uprooted by pigs in many places and was prominent in their faeces.

Although some of the palatable woody plants were browsed by goats they were commonly growing strongly within protective envelopes of unpalatables. Most of the food of the goats came from the swards of introduced grasses, and they ate only small amounts of the native tussock grasses. With one exception the subantarctic woody associations seemed to be holding their own against browsing. This exception was where goats had browsed the salt-tolerant, but palatable, Hebe elliptica on a windward cliff top and allowed the wind in to erode the rata canopy beyond it.

This then seemed to be a population of goats living at their extreme of environmental tolerance, limited in range, static, and not threatening any plant communities. Ten years later, in 1983, the goat population and the marked vegetation plots and photopoints were re-examined (Campbell and Rudge 1984). The number of goats counted over part of the goat range was similar to what was in the same area in 1973 (52 and 58 respectively). Their range had not increased but some were seen feeding at higher altitudes than before. Some of the vegetation transects were identical plant for plant with the transect diagrams and photographs of ten years earlier. In other sites, woody vegetation had advanced over the swards, tussocks, and moorland. By contrast, a site where browsing had broken the forest edge of Hebe elliptica in 1973 was almost totally transformed to Poa litorosa grassland by 1983 (Figure 2).

The greatest change was seen and measured in the lowland Chionochloa tussock grassland. On three transects within the area common to goats and pigs, the sparse cover had been reduced by 96, 74 and 34 percent and was almost completely eliminated; and at two sites in the range occupied only by pigs it had been reduced by 8 and 11 percent. Goats ate only small quantities of this tussock in 1973 and the bulk of their feeding time was spent on the swards of introduced fine grasses. Nonetheless the cumulative effect of ten more years of light cropping, together with rooting and tearing by pigs, was enough to kill most of the remaining adults and suppress seedlings. The visual effect was striking in paired photographs taken ten years apart (Figure 3). Clearly, goats and pigs together are capable of eliminating this tussock from the lowland.

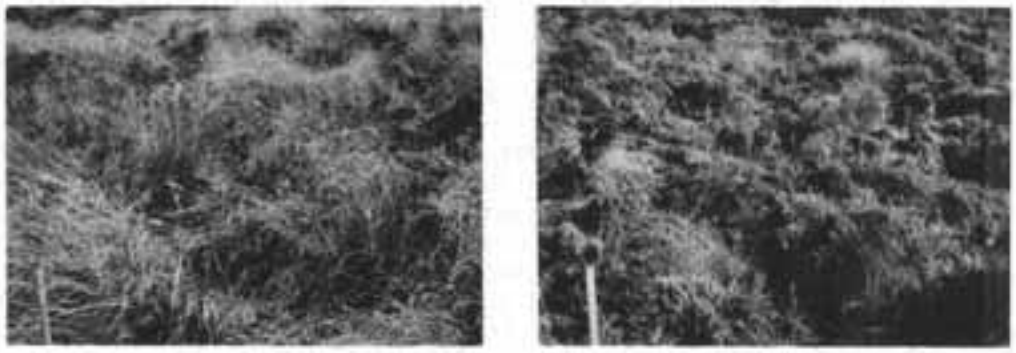

Figure 3. Reduction of Chionochloa antarctica tussock in an area inhabited by goats and pigs. Left 1973, Right 1983.

the goats. These responses and the physical difficulty of hunting through thickets would work against further control.

Autopsy information gathered during the following years of goat control confirmed the 1972 predictions (Parks 1984a). By 1981-83 productivity of the females had more than doubled to 170.3 kids/100 females/year. Whereas only 1.5 percent of the females bred twice each year in 1972, 23 percent were doing so in 1981. This meant that the population had a doubling time of about 20 months. Control was also physically hampered by the resurgent vegetation (Parkes 1984b).

THE AUCKLAND ISLAND POPULATION

The Auckland Island group lies some 400 km south of the mainland of New Zealand and is classed among the world's subantarctic islands (Figure 1). The main island covers 45,975 ha and rises to 665 m. They were discovered in 1806 and pigs were liberated on them the next year (McLaren 1948). Pigs prospered on the large subantarctic endemic herbs and drastically reduced their abundance both in the flora and vegetation (Challies 1975). Whalers, sealers, shipwrecked sailors, explorers and would-be settlers all burnt the vegetation in various parts of the islands. Thus when goats were set free at different times in the late 19th century as food for shipwreck castaways, it was usually into habitats that had been modified already (Rudge and Campbell 1977). Of the ten known liberations, eight simply died out and one population was exterminated in 1941-42. Only one has survived, since at least the turn of the century, on the relatively sunny (but still windy) northwestern end of the main island. The precise reasons for this differential success are not known, but, as it was only at the northern sites that animals endured for any time, the islands must be marginal in climate and food resources for goats.

In 1973, when the first survey was made of the goat population and its influence on the vegetation, the population consisted of some 100 animals scattered over roughly 2000 ha of range (density 0.05/ha). Distribution seemed to be limited by a deeply channelled stream, dense belts of scrub, and wet windy conditions at the higher altitudes that animals would have to pass through to reach other parts of the island. The goats spent virtually all of their time in feeding activity. Productivity could not be assessed, but few young animals were seen.

In 1973 the distribution of vegetation and of human activity (burning, cutting) showed that the vegetation had been altered by man in much of the goat range (Rudge and Campbell 1977). Woody vegetation had regenerated despite the goats after the era of burning. On the relatively sheltered shores it had returned to a rather simple forest in which southern rata (Metrosideros umbellata) was dominant over five other woody species. The forest had sparse ground and shrub layers whether or not goats lived there, giving it the misleading appearance of having been eaten out. With increasing exposure and altitude, essentially the same combination of plants, but with varying relative dominance, formed scrub associations with moorland or tussock in between. On coastal sites the tussock grass Poa litorosa formed continuous cover. In the upland above 300 m another tussock grass, Chionochloa antarctica, replaced scrub. At lower altitudes this tussock alternated with the scrub. It seemed to have been an abundant colonizing plant in the recent past, giving shelter to

DISCUSSION

The population performance and influence of goats on the Kermadec Island matches the general perception of these animals on islands. They were introduced into forested habitats which, in one instance, had already been greatly modified by man. On Macauley Island they were able to reduce that habitat to a floristically and structurally simpler grassland which evidently still suited them. The population density was high yet they remained prolific but with high pre-natal and juvenile mortality. On Raoul Island the continuity of the forest cover belied the great changes that had been inflicted internally on its structure and floristic composition. Although the forest was not scarred with canopy gaps, erosion (other than around the craters) or large areas of goat-induced swards such as on Macauley, there were clear signs of progressive deterioration. The benefits for the vegetation that could be expected from reduced numbers were indicated in the vicinity of the Meteorological Station. But conversely, the goats living in that area gave warning that with a reduced density and improved food supply, productivity could rise. A similar response was found during control on Santa Catalina Island, California (Coblentz 1982).

When control was undertaken on Macauley Island it was easy to exterminate the population because there was so little cover. The grassland responded immediately, but the remnant animals were easy to see and shoot 4 years later. On Raoul, probably less than half of the population was removed from the forest in the first effort in 1972. Thus, both the animals and the vegetation had time to respond in ways which made further control work progressively harder. The forest understorey became more dense and grew rapidly to head height, hindering hunting by man and dogs. This resurgent food source was manifested in the remaining goat population by improved body size, growth rates and condition; and, most importantly in greater productivity. But by 1982 the population could be counted in tens rather than thousands, and extermination was in sight. At that stage numbers were capable of doubling every 20 months if control work lapsed (Parkes 1984a).

On both Macauley and Raoul Islands, there was abundant evidence that the populations were making severe demands upon the vegetation, and were an obvious management problem. On the Auckland Islands it was not even clear whether or not there was a problem, because the population did not seem to conform to this traditional model of high numbers producing an impoverished habitat. Eight known liberations had failed naturally. The only remaining population was at a low density, seemingly unproductive and possibly even declining. With one exception, there seemed in 1973 no serious impact on vegetation. Despite the goats, woody vegetation had steadily recovered from man's disturbance for about 100 years. Although this population was in a valuable Nature Reserve it seemed to be at least tolerable, and was perhaps one of the few candidates for genetic conservation as it was surviving at the extreme of environmental tolerance.

These conclusions for Auckland Island had to be revised when the marked plots were re-examined one decade later. Although woody communities generally had continued to advance on appropriate sites, the Hebe/rata coastal fringe had disintegrated and receded, to be replaced by unpalatable Poa litorosa tussock grassland. This dramatic change was betrayed clearly by logs, and standing dead and dying trees. Photographs taken in 1874 suggest that this coastal forest community had been even more extensive then.

In the lowland herbaceous communities, changes were not as immediately obvious. Indeed, if the 1973 photographs had not been used in the field in 1983 it would have been difficult to register the virtual elimination of Chionochloa based on the evidence of memory. Unlike woody plants, dead tussocks leave no durable evidence. However, large dead tussock bases were found in places under the advancing margin of scrub, indicating something of the natural succession. This process may even have been assisted by goats eating the tussocks, because woody plants have difficulty establishing in their shade (Zotov 1965). The evidence from 19th century photographs and on the ground strongly suggests that Chionochloa was indeed abundant in that period after burning. Goats and pigs have slowly reduced it, and the decade just monitored has seen the virtual removal of its last remnants.

Because lowland Chionochloa often gets replaced by woody vegetation, its loss need not in itself be serious, but there is the implication that goats may then exploit it at higher altitudes and so migrate round the stream heads to other parts of the island. On the other hand they may remain within the area of their preferred food, the introduced grass swards, and gradually decline as the woody vegetation continues its steady advance. There seems little chance that in their present impoverished habitat they would achieve the explosive productivity seen in the Kermadecs, but even that cannot be guaranteed. The resurgence of the sheep population on Campbell Island (some 100 km further south) in the 1960's, seemed equally unlikely (Wilson and Orwin 1964, Rudge 1984b). If, by some means the goats reached the sheltered forests of the eastern cost, where the understorey is richer, productivity could well rise. At present it seems that within their present range the goats are competing with a simple but highly adapted vegetation and that there is a fine balance to which neither can gain the ascendancy. Although this is an interesting scientific conundrum it must defer to the more important requirements of the Nature Reserve.

The question remains as to whether it is necessary to control these goats or just keep watch on them. The possibility that they will extend their range remains small but is now identifiable. The issue is complicated by the presence of pigs, as they too browse and root up Chionochloa. Even before the goats were liberated, pigs had removed an entire vegetation type of large subantarctic endemic herbs and tussocks (Challies 1975). The goats colonized an impoverished habitat and have survived in it during the slow recovery of the woody elements. Their measured impact in recent times is to accelerate the elimination of Chionochloa aided by pigs. Removing goats alone (which would be simple compared with Raoul Island) would be of limited benefit so long as pigs remained. Hebe elliptica forest would recover but the large endemic herds would not. If pigs alone were removed a whole new palatable herbaceous flora would reappear and the goats might then become more productive and extend their range.

From these comparisons it is possible to make some specific comments and also to provide numerical insights into what has happened in many places where goat control has been so protracted (e.g. the Galapagos Islands, Lewin 1978). Clearly goats are adaptable and resilient animals capable of dramatically modifying the habitat and yet still prospering in it. Each of these three examples posed a different problem, and the solutions described all contribute to the general question of goat control, or of preservation in a genetic conservation programme.

In the Kermadec Islands the problem was obviously one of massive infestations of thriving populations. On Macauley, the degraded open habitat allowed the population to be almost annihilated in a single operation. Regrowth of the grass and herb vegetation was not a problem in completing the task because it remained below waist height. On Raoul Island, a limited investment in 1972 brought limited progress towards extermination, but a massive penalty in terms of dense forest regrowth, and heightened productivity in the goats. The exercise was immediately doomed to be of long duration, and not until 1984 was the end in sight. Clearly in habitats where plant growth is rapid, drip-feed annual budgets are not appropriate to the biological realities. Large costs at the start of a campaign, and a stated consequence of appropriate techniques, are more likely to be successful and more satisfying for the operators.

In the Auckland Islands it is still not clear that there is a goat problem beyond the doctrinaire one of having them in a Nature Reserve. Their impact has been, and still is, rather subtle, and clearly there is a long drawn-out battle being fought between them and the well-adapted subantarctic vegetation. This, and the intertwined contributions of human impact and pigs, have emerged only through long-term measurements and must all be taken account of in managing the island. But from what we now know of goat productivity when food supplies improve, we can broadly predict what would happen if these animals extended their range to richer areas. At present such an extension remains only a possibility, but because of it the case for preserving this population in a genetic conservation programme is greatly diminished.

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