Simply sand?
Ocean Beach dunes, Hawkes Bay

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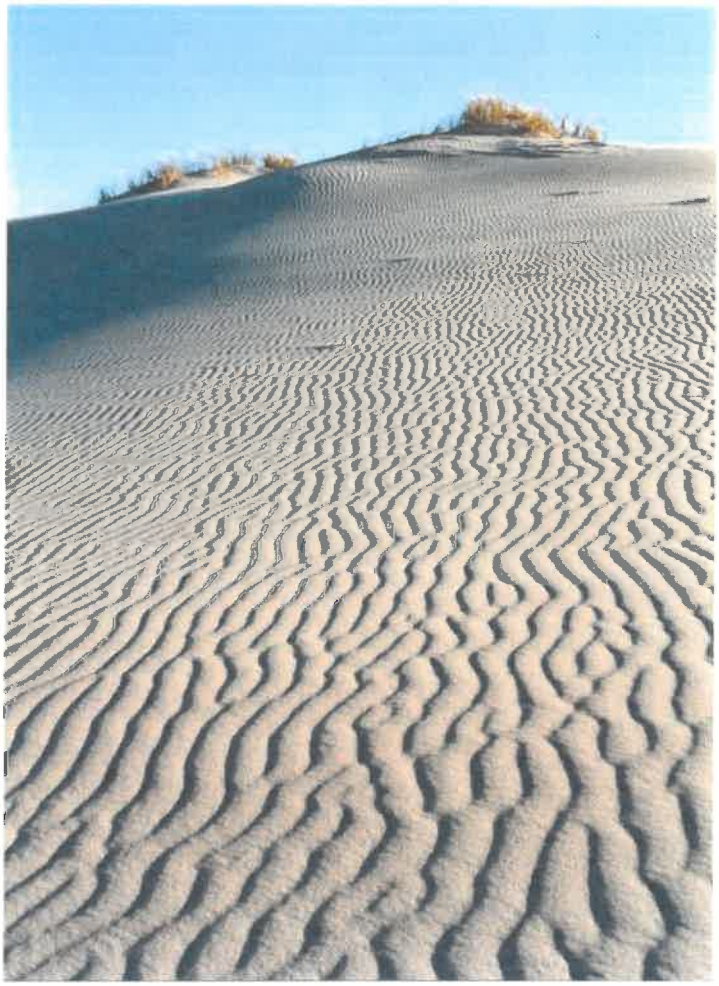
Published by
Department of Conservation
Head Office, PO Box 10-420
Wellington, New Zealand



This report was commissioned by Hawkes Bay Conservancy

ISSN 1171-9834

Reference to material in this report should be cited thus:

Walls, G., 1998
Simply sand? Ocean Beach dunes, Hawkes Bay. *Conservalion Advisory Science Noles No. 21.3,* Department of Conservation, Wellington.

Keywords: Dune vegetation, dune stability, Ocean Beach, Protected Natural Areas, Eastern Hawkes Bay Ecological District.

Summary

Ocean Beach is a large important Hawkes Bay sand dune system, lived on by people for centuries and traditional home of native sandbinding vegetation and the small animals it shelters. Of note are pingao (*Desmoschoenus spiralis*), prized for its golden leaves and symbolic of the tension between land and sea, of Tane Mahuta and Tangaroa, and its companion the silvery spinifex (*Spinifex sericeus*). This research set out to discover how the dune vegetation was changing over time, what were the agents of change, what was the impact of browsing mammals and human recreationists, and what was causing the decline of pingao.

The results of eight years of study (1989-97), centred around exclosure plots, show that the vegetation cover increased overall, due to weed invasion and lessened browsing pressure. Marram grass *(Ammophila arenaria)* is a serious weed of the more mobile dunes, squeezing out native plants by competition and stabilising the sand so that it is unsuitable for pingao and spinifex. Self-sown pines and pampas grass *(Cortaderia selloana)* are major threats to the more stable rear dunes and dune hollows. Pasture grasses and herbs are colonising relatively stable sites, to the detriment of pingao. Adult pingao naturally dies back once it stabilises a site, but sends new growth out into fresh sand. Pingao seedlings need moist open hollows to establish, and are vulnerable to being buried or undermined by shifting sand. Their greatest threat though, comes from rabbits, which eat them avidly, thereby preventing genetic evolution in the system. Spinifex is highly adapted to life in dynamic sand, and is capable of elongating more than five metres in a single year. Pingao and spinifex can readily coexist, but both get flung back when they grow down too close to the sea. Cattle are highly damaging to dune vegetation, especially pingao. Sheep, horses and feral goats have lesser though still significant impacts. Possums and hares, though present, have little impact on the dune vegetation. Off-road vehicles, especially quads and trail bikes, are particularly damaging to dune faces.

It is recommended that conservation management begin as soon as possible at Ocean Beach, to halt the decline of the natural and cultural features of the dunes. A healthy partnership between the land custodians - Haupouri Station Trust and the Department of Conservation - is necessary. So is consultation with the other key people and organisations involved. Essential for successful conservation are legal protection of the dunes, fencing, pest control, ecological monitoring and public education. It is suggested that a steering group be set up to guide these tasks.

1. Introduction

Ocean Beach is a great wild sweep of sand just south of Cape Kidnappers (Figure 1). In conservation terms - size, diversity and naturalness - it is the best remaining dune system on the eastern North Island between East Cape

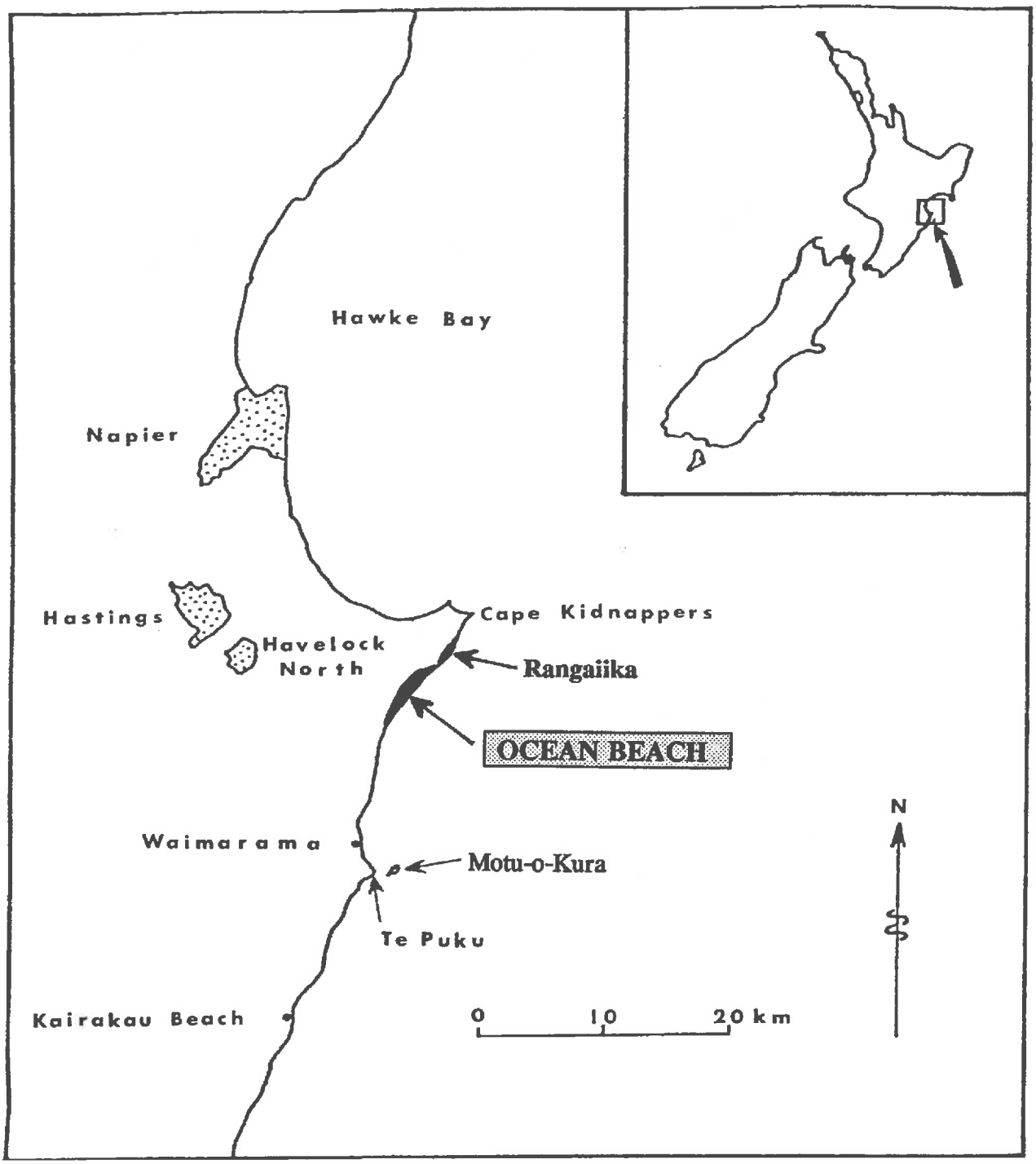


Figure 1. Location map, Ocean Beach, Hawkes Bay.

and Wellington. Nevertheless, it has been severely degraded by farming practices, introduced animals, weeds and off-road vehicles. The degrading influences are mostly still there, despite one of the custodians being the Department of Conservation (the other is Haupouri Station Trust, a traditional Hawkes Bay commercial farming venture).

For me, Ocean Beach is a place of inspiration, insight, peace and delight, but also of great despair. I came to Hawkes Bay in the hope of being able to help protect the natural and cultural features it possessed in abundance. Thirteen years on, despite much survey, research, reporting and negotiation with the landowners, tragically little conservation progress has been made. This report is an account of my connection with Ocean Beach as an ecologist. It tells much of the details of my research there. It tells little of my exploration of its contours and seasons over the years, or of the depth of my feelings for its spirit: that requires a more artistic forum than this.

Ocean Beach takes the form of a long gentle curve, pregnant with billowing dunes (Figures 2 & 23). The dunes are backed by a coastal flat behind which is a spine of steep hills containing a scattering of trees of titoki *(Alectryon excelsus)*, karaka *(Corynocarpus laevigatus)*, ngaio *(Myoporum laetum)* and ti kouka (cabbage tree, *Cordyline australis*), echoes of the former lush coastal forests. The dunes are the natural home of our two native sandbinding plants, the silvery spinifex *(Spinifex sericeus)* and the golden pingao (nga tukemata o Tane, *Desmoschoenus spiralis*). Both grow on the most mobile seaward clunes, but are under threat from competition with the introduced marram grass *(Ammophila arenaria)* and from browsing and vehicle damage.

The rear dunes are quite stable and are vegetated in a low cover made up of varying proportions of spinifex, *Coprosma acerosa*, hare's tail *(Lagurus ovatus)*, knobby clubrush *(Isolepis nodosa)*, tauhinu *(Cassinia leptophylla)*, bracken *(Pteridium esculentuin)* and exotic pasture grasses and herbs. There are clumps of blackberry (*Rubus fruticosus* agg.) and scatterings of self-sown pines in places (Figure 38). In the mid section of the dune system the dune hollows are quite damp, even in high summer, and there are small wetlands of jointed rush *(Leptocarpus similis)* and ever-increasing expanses of pampas grass *(Cortaderia selloana)*. In the past, the rear dunes were probably clothed in low windswept forests made up of totara *(Podocarpus totara)*, ngaio, ti kouka, kanuka *(Kunzea ericoides)*, manuka *(Leptospermum scoparium)* and various tree and shrub daisies. Karaka would have arrived with the first settlers.

The Ocean Beach dunes are home to many animals. Most go unseen because they are small or come out at night. Most conspicuous are the farm animals - cattle, sheep, horses and dogs - that are there from time to time. Less so are rabbits, hares, possums, hedgehogs, rats, mice, stoats, ferrets, weasels and feral cats. All these smaller introduced pests hide in the vegetation cover at the rear of the dunes and operate on the wider dune area when humans are not in evidence. They are responsible for preventing blue penguins from using the dunes. So are dogs: I have found penguins killed in the dunes by dogs. Without these predators, penguins would be plentiful and would breed there. So too would small petrels such as diving petrels and storm petrels. The only evidence I ever found of them was a single burrow in the northern dunes that

could have been made by a diving petrel. I once found a crash-landed giant petrel in a dune hollow, and a gannet and a fairy prion on other occasions.

Other birds I have recorded in the dunes include southern skua, black-backed gull, red-billed gull, white-fronted tern, white-faced heron, pied stilt, spur-winged plover, paradise shelduck, welcome swallow, pipit, banded dotterel, skylark (including one albino), yellowhammer, greenfinch, goldfinch, chaffinch, redpoll, starling, silvereye, magpie, blackbird, songthrush, dunnock, house sparrow, pheasant, California quail, pukeko, black shag, variable oystercatcher and kahu (Australasian harrier).

Lizards should be abundant in the dunes, but for the predators. I have seen only common skinks *(Leiolopisma nigriplantare polychroma)*, and no geckos. There is certainly enough invertebrate life to sustain lizards. It includes native sand specialists such as the big sand scarab, whose tracks can be seen meandering over the exposed sand on calm mornings, and whose great grubs fatten beneath driftwood logs. It also includes the endemic katipo spider, black earwig, darkling beetles, ground beetles and carabid beetles, and a wealth of native and introduced sandhoppers, woodlice, centipedes, millipedes, bugs, moths, small butterflies, spiders, mites and springtails. Most surprising perhaps is the abundance of garden snails, their shells much thicker than in the domestic situation, and many little snails.

This study focused on the vegetation and the sand, guided by the ecological presumption that, in general, what happened to them had direct implications for the animals, especially the specialist native fauna.

Ocean Beach is one of the highest ranking RAPs (Recommended Areas for Protection) in the wider Hawkes Bay region, and is enshrined as such in the Department of Conservation's PNAP (Protected Natural Areas Programme). The PNAP survey document highlighting Ocean Beach has been published (Maxwell et al. 1993). The beach system is also recognised for its natural and cultural attributes in the draft Hastings District Plan and in the draft Hawkes Bay Regional Coastal Plan.

People have lived on the Ocean Beach dune system and its hinterland for many centuries - it is one of the most important archaeological landscapes in New Zealand. I have taken several archaeologists there, and together we have traced many clues to the people who lived and died there in the past. People flock to the beach still, especially in summer. Their presence is both a blessing and a threat: on the one hand they value it as a wild coastal place, on the other they wish to ride their destructive off-road vehicles all over it, unaware of its fragility, and help create the push to exploit and "develop" the area.

In 1984, even before I had been appointed DSIR (Department of Scientific and Industrial Research) Regional Botanist to Hawkes Bay-East Coast, I was first made aware of the conservation values of the Ocean Beach dunes, and the threats to them. Jody Stent wrote to DSIR headquarters in Christchurch on behalf of Otatara Roopu Raranga, a group of Hawkes Bay artists and traditional Maori weavers. Her plea was for DSIR to investigate the plight of the pingao, so beloved of the weavers for its rich natural gold and its coastal symbolism, at Ocean Beach. This study is born out of that plea.

2. History of research and conservation

What follows next is a potted history of the study and the attempts at protection that I have undertaken over the years.

1985: As soon as I reached Hawkes Bay, as DSIR Regional Botanist, I went to see Jody and the other weavers, then headed out to Ocean Beach for a look. It was obvious to me as an ecologist that the pingao, although relatively common, was under threat. It was being eaten by cattle, goats, sheep, horses, rabbits, possums and hares. It was being invaded by marram grass.

I discussed the situation with other ecologists, DSIR managers and the weavers. We resolved that something needed to be done if the wild dunes and the pingao were to survive. I developed a working relationship with the Haupouri Station manager, who seemed interested and sympathetic. I began research on the issues surrounding the concept of protection.

1986-87: Working with Haupouri Station staff, I got them to reconsider their management practice of wintering cattle on the dunes. Sheep and horses were kept off the dunes more actively, too, and the numerous feral goats were cleaned out.

I visited the dunes regularly, in an effort to get to know them and their ecology better. I learned that wind and sea were shifting the sand constantly, often huge quantities in a short time, and that whilst spinifex and pingao could go with this flow, the marram grass acted to stifle it, with abrupt disruptive results.

I saw whole dunes blow away and others form. I saw hollows fill with water and become wetlands, only to dry again and disappear. I saw weeds on the move. I found evidence of predation on sea birds, and found others grounded by storms. I witnessed the mindless trashing of the dunes at the hands of off-road vehicle joyriders.

I learnt also the degree of archaeological richness of both the dunes and their hinterland. Even when I had the place to myself, I always felt the presence of those who had lived there, with the elements and the seasons, the fauna and flora, for so long.

Jody and I negotiated with the Haupouri Station manager for an area where we could fence off the dunes to protect the pingao from stock and vehicles. We began putting the case together to seek funding.

1988: I continued observing the dune system and the pingao. Nothing I saw made me feel easy about the long-term future of the dunes and the pingao. I began to suspect the lack of recruitment of pingao seedlings

was critical and that rabbits were the major culprit, and designed an exclosure study to test this.

Negotiations with Haupouri Station continued, and with their blessing Jody and I submitted an application to Lottery Grants Board for funding to fence off the northern section of the dunes (roughly 15% of their area).

1989: The Lottery Grants Board application was successful. However, Haupouri Station Trust members, with no warning, quashed the fencing initiative. The reasons for that decision still aren't totally clear, but relate to issues of access, control and partnership.

I was permitted to extend the study, though, and set up a series of exclosures, vegetation plots and photopoints to examine the impacts of different browsing animals, vehicles, weeds and sand flow on pingao, spinifex and other native dune plants. This study continued to October 1997, with regular inspections, exclosure maintenance and analysis of data, as an official Department of Conservation research project, funded by Science and Research Division and supported by the Conservancy. It is described in detail in the following sections of the report.

1990-96: With my transfer from the DSIR to the Department of Conservation in 1990, the prospects for protection of the Ocean Beach dunes looked brighter than before. This was because it brought the research into the agency that:

(a) had management responsibility for the Crown coastal strip of the dunes;

(b) had a public conservation advocacy role in the region, of which Ocean Beach is the prime dune and beach system;

(c) had a working relationship with the landowners of the area over a whole range of issues;

(d) had responsibility for the Protected Natural Areas Programme (PNAP) which sought to identify and help conserve the best remaining natural areas in the region;

(e) had responsibility for archaeological and historical resource protection issues;

(f) had practical knowledge and resources for fencing, revegetation, weed control and animal pest control;

(g) had a working partnership with local Maori over cultural materials, their use and conservation;

(h) had responsibility for protection of threatened flora and fauna;

(i) had working partnerships with the local authorities.

In 1992 the Department of Conservation carried out a PNAP survey of the Eastern Hawkes Bay Ecological Region, in which Ocean Beach lies. It identified the Ocean Beach dune system as of highest priority for protection, because of its wealth of natural and historic attributes. The report from this survey was published and distributed widely (Maxwell et al. 1993).

Several meetings were held during this time between key members of the Department of Conservation and Haupouri Station/Haupouri StationTrust. There was also an interchange of letters and phone consultations. All of these gave the appearance of progress towards a close partnership between the Department of Conservation and Haupouri Station Trust, in which virtually the whole dune system would be set aside for protection.

It seemed as though the interests and aims of the two parties came together neatly, and that what would serve the station best for farming would also serve conservation well.

What was verbally agreed included:

- The majority of the dune system would be protected, fenced on the inside to exclude domestic stock; this would be a joint Department of Conservation/Haupouri effort, as would fence maintenance.

- The Department of Conservation would contribute to planting of trees (native preferably, but possibly also exotics) at the rear of the dunes, to prevent sand encroachment on to the farmed flats.

- The Department of Conservation would ensure continuation of pingao on the dunes, by weeding, animal control and planting where necessary; it would have a monitoring system in place for indicating when such work was necessary.

- The Department of Conservation, in conjunction with Haupouri Station, Hawkes Bay Regional Council and Hastings District Council, would put a campaign of public education in place to heighten awareness of the value of the dunes and to gain support for their conservation and wise use.

To date - February 1998 - none of this has happened.

Meanwhile, the dune study progressed to the stage where the finger could be pointed at the chief threats to the duneland ecosystem and the pingao:

- weeds: marram grass and pampas grass (the worst); self-sown pines, self-sown willows and blackberry (lesser problems);

- rabbits (the worst browser), possums and hares (relatively minor impact);

- straying domestic stock, especially cattle;
- off-road vehicles (especially damaging to archaeological sites and dune faces).

All of these threats could be managed relatively easily.

1997: Restructuring of the Department of Conservation axed a number of positions based in Napier, including that of Advisory Scientist. As a result, I wound up the duneland study, the final field measurements being made in late July-early August. A visit was then made with Alan Lee of the Ahuriri Field Centre to ensure the exclosure site would continue to be used by the Department of Conservation for monitoring the condition and trend of the dune vegetation.

At the time of the field measurement, I had a long conversation with Warwick Hansen, Haupouri Station Manager. He expressed the opinion that he and the Trust wished to wait for the final Hastings District Plan and Hawkes Bay Regional Coastal Plan to appear before proceeding with any duneland protection. Encouragingly, by the time of the visit with Alan Lee, Warwick seemed open to continued dialogue with the Department of Conservation.

Otatara Roopu Raranga has remained in the background as an interested and supportive observer. It has kept its resources potentially available for protection of the dunes, but cannot be expected to do so forever.

3. Study design and methods

The study of the Ocean Beach dune dynamics was undertaken to address some basic questions:

1. How was the vegetation on the mobile dunes changing?
2. What were the agents of vegetation change?
3. What was the impact of browsing mammals and human recreationists?
4. Was the pingao dying, and if so, why?

The field work was founded on the hypothesis that most of the vegetation changes were not natural, but the result of impacts by browsing mammals, machines and weed competition. Accordingly, three fixed plots or quadrats were designed and established in winter 1989. One of these (Plot 1) was a paired exclosure set-up; the others (Plots 2 and 3) were simply defined by pegs in the ground. The plot locations are illustrated in Figure 2, design of Plot 1 in Figure 3, and typical monitoring sheet in Figure 4.

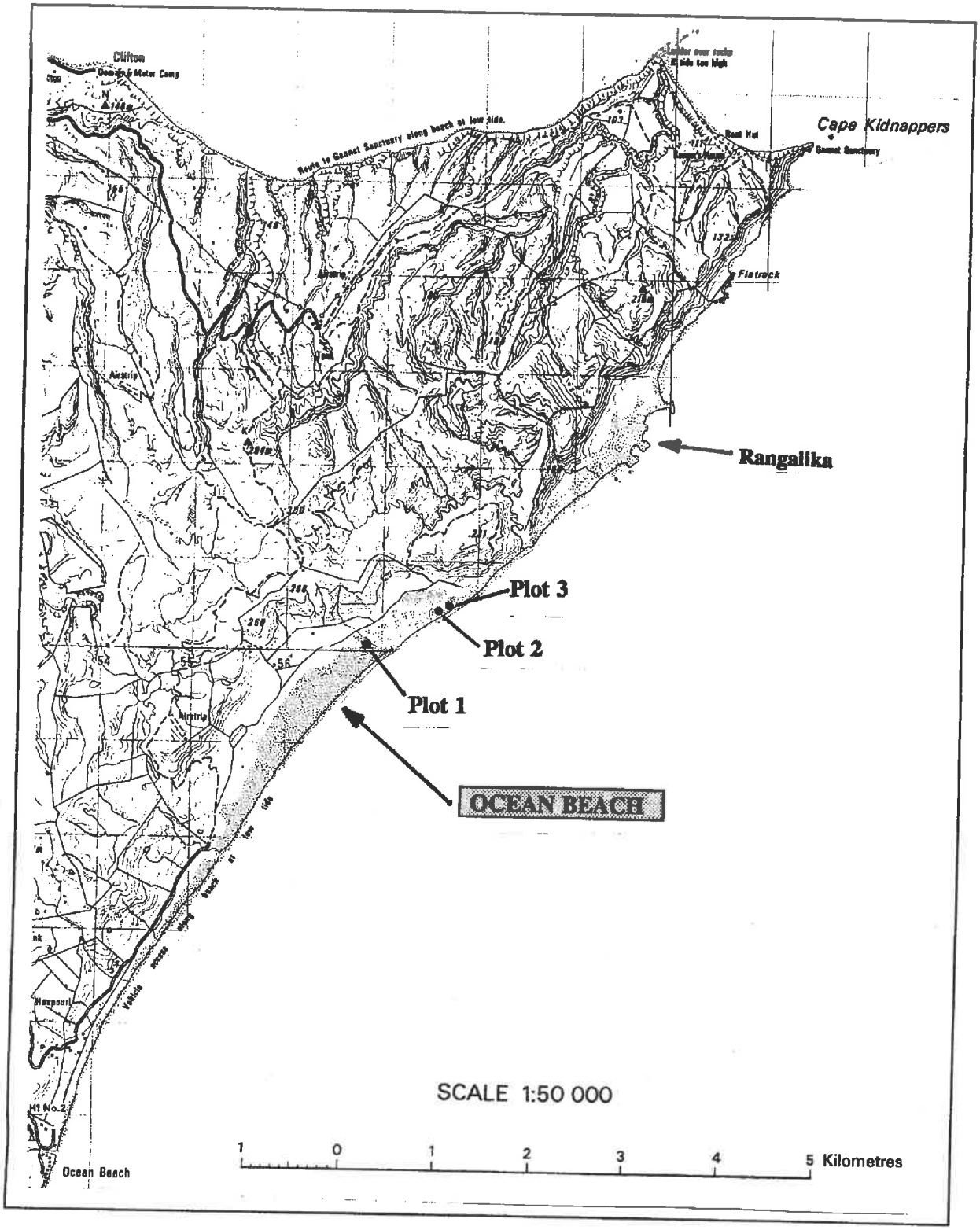


Figure 2. Location of study sites, Ocean Beach.

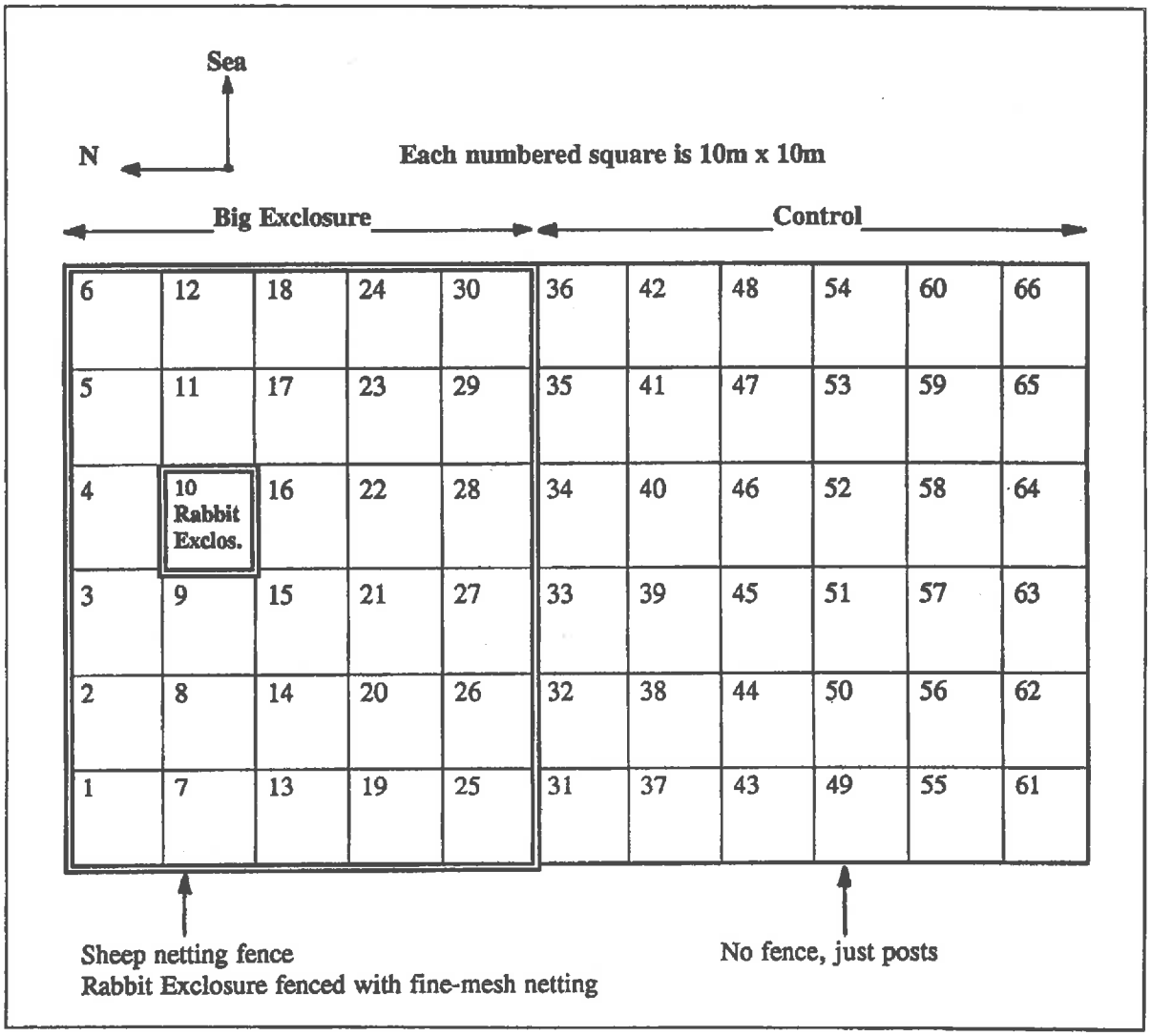
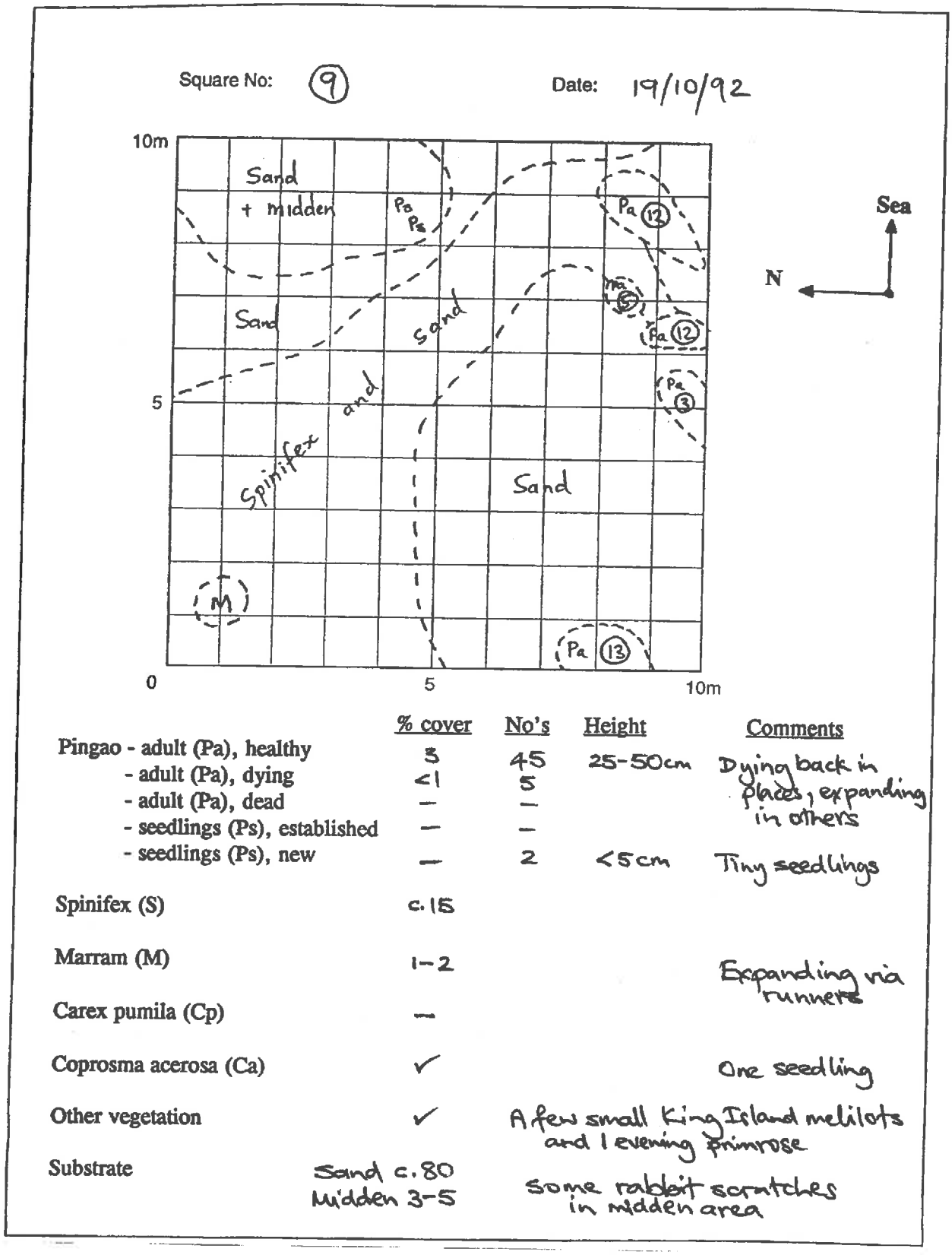


Figure 3. Design and layout of Plot 1, Ocean Beach.



	% cover	No's	Height	Comments
Pingao - adult (Pa), healthy	3	45	25-50cm	Dying back in places, expanding in others
- adult (Pa), dying	<1	5		
- adult (Pa), dead	—	—		
- seedlings (Ps), established	—	—		
- seedlings (Ps), new	—	2	<5cm	Tiny seedlings
Spinifex (S)	c.15			
Marram (M)	1-2			Expanding via runners
Carex pumila (Cp)	—			
Coprosma acerosa (Ca)	✓			One seedling
Other vegetation	✓			A few small King Island melilots and 1 evening primrose
Substrate	Sand c.80 Midden 3-5			some rabbit scratches in midden area

Figure 4. Example of field sheet used for plot monitoring.

PLOT 1

Plot 1 (Figures 3, 28, 30, 33 & 35) was by far the biggest and most complex of the plots, and as such constituted the heart of the study. Its location was chosen because of the relatively high number of pingao seedlings on that part of the dune system, the presence of adult pingao, spinifex and marram grass in reasonable quantities, and the combination of building and deflating dunes.

A large exclosure (60 m x 50 m in size) was built to keep out domestic cattle, sheep and horses, feral goats and off-road vehicles. It was constructed of tanalised pine posts and sheep netting, and with regular maintenance proved effective for the duration of the study. Because of my desire to study complexity, as well as the impossibility of finding a homogeneous site, the adjacent control (non-treatment) plot ended up at 60 m x 60 m in dimension. Within the big exclosure a smaller rabbit exclosure, 10 m x 10 m in size, was built using small-mesh galvanised netting dug at least 30 cm into the sand. It was necessary to renew the rabbit netting twice because of rust. A couple of cages, 2 m x 1 m in ground area and covered in the same small-mesh netting, were installed as well, to prevent possums getting to pingao seedlings. One stayed in place inside the rabbit exclosure, whilst the other was moved about from time to time to cover groups of tiny ephemeral seedlings.

PLOT 2

Plot 2 was 1 km to the north-east of Plot 1. Unlike Plot 1, which was representative of vast areas of the mobile dunes, it was chosen to follow a very unusual circumstance. At this site, a broad flat backed by large mobile dunes, adult pingao was growing where there was no sand movement and plenty of other vegetation: in fact the sand substrate was totally covered in vegetation (apart from pingao, mainly *Carex pumila*, knobby clubrush and pasture grasses and herbs).

The plot was simply a 10 m x 10 m square encompassing as much pingao as possible.

PLOT 3

The third plot was another representative one. Seventy metres to the north-east of Plot 2, it was right on the seaward face of a small foredune. There, a pingao plant cascaded down the sand among spinifex, occasionally reached by high seas. I put in the plot, a mere 5 m wide strip, out of curiosity, to watch the interplay of the sandbinders and the sea right where they met.

PHOTOPOINTS

A number of photopoints were set up. Most of these were centred on the plots, but a few were chosen elsewhere to illustrate other vegetation changes.

RECORDING METHODS

Detailed measurements of the plots and photopoints were done at the following times:

- late June-early July 1989
- mid June 1990
- late July-early August 1991
- mid October 1992
- mid-late December 1993
- late October 1995
- late July-early August 1997

On these occasions the plots were measured to a standard formula I devised. Plot 1 was gridded up into 10 m x 10 m squares, and each of the 66 squares was measured individually. Within each, the following were recorded:

adult pingao:	no. of live tufts; % cover
pingao seedlings:	no. alive; no. dead
spinifex:	% cover
marram grass:	% cover
Carex pumila:	% cover
Coprosma acerosa:	% cover
other vegetation:	% cover
substrate (sand, sediment, midden):	% cover of each.

Besides this, a sketch map of the vegetation of each square was made (Figure 4 is an example). Observations on ecological processes were noted.

For Plots 2 and 3, the same procedure was followed, with minor adaptations because of their different nature. The whole process of measuring the three plots took two long days each time.

Interested in the movement of sand, and aware that it drifted or deflated according to prevailing wind conditions, I marked posts in Plot 1 so that I could regularly record the sand levels on them. In the time period of the study (eight years) I measured the sand levels 23 times - almost every time I visited the plots to check the exclosures, do maintenance on them or measure them.

4. Results

4.1 PLOT 1

4.1.1 Vegetation cover

In both the big exclosure and the control, the overall vegetation cover steadily increased over time, by 83% and 68%, respectively (Figure 5). These trends are very similar, though the slightly greater proportional increase in the big exclosure may be due to the lack of browsing by big animals. By stark contrast, the vegetation cover in the rabbit exclosure skyrocketed, with a more than 20-fold increase. This superficially suggests that rabbits were responsible for a radical impact on the vegetation. I believe that is true, but that another influence was also responsible for the vegetation increase: that of sheltering provided by the close-mesh netting used to keep out the rabbits. I think that the mesh broke the wind just enough to make give extra stability within the exclosure, and this allowed the vegetation to grow more easily than outside. Without a replication to test the relative effects of these two influences, it is impossible to say which was the greater. With this exclosure evidence though, coupled with direct browsing observations, I am certain that rabbits are responsible for major impacts on the vegetation of the Ocean Beach dunes.

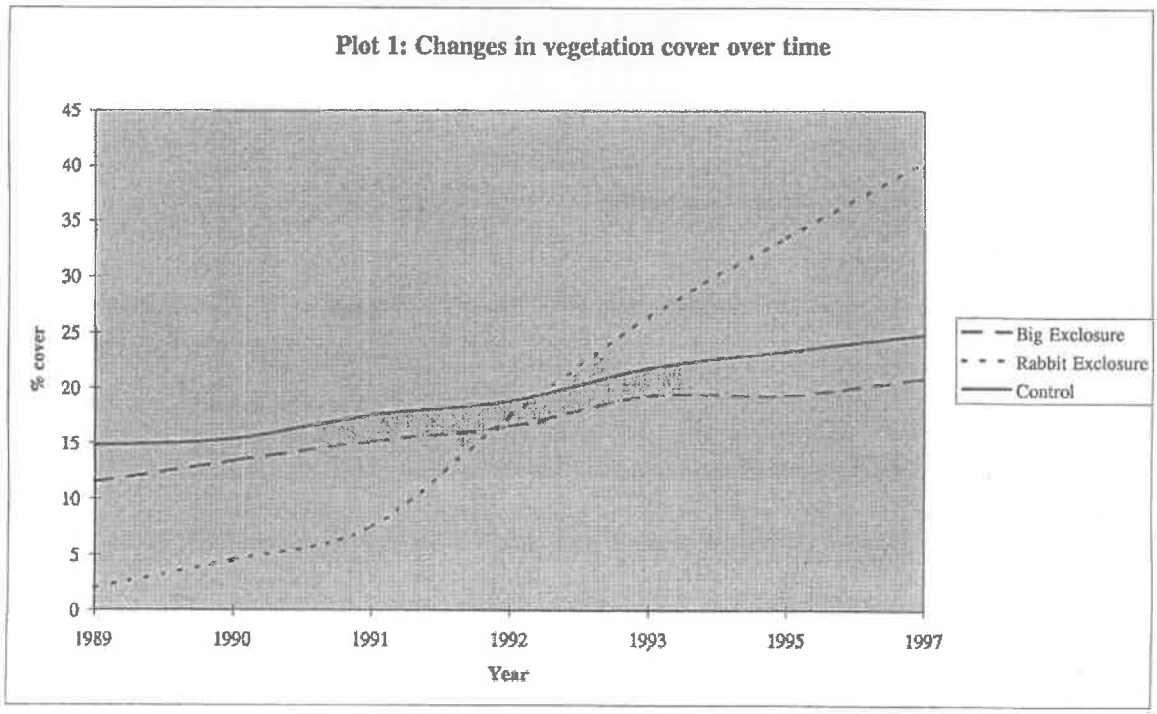


Figure 5. Overall changes in vegetation cover over time, Plot 1.

Figures 6-8 give a more detailed breakdown of the vegetation changes. They show that the changes within the big exclosure and the control (Figures 6 and 7) were very similar, and that most of the change was contributed by a large increase in marram grass (see Figure 33). The proportional increase was greater within the exclosure, suggesting that browsing by cattle and sheep

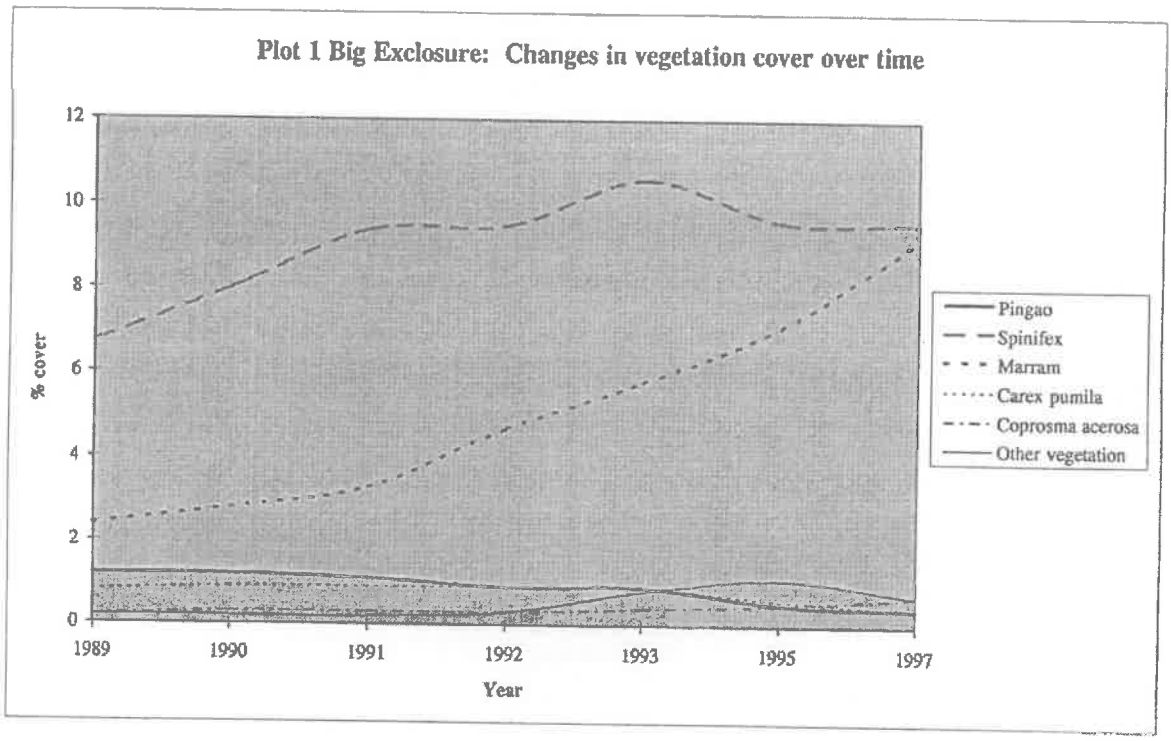


Figure 6. Changes in vegetation cover, big exclosure, Plot 1.

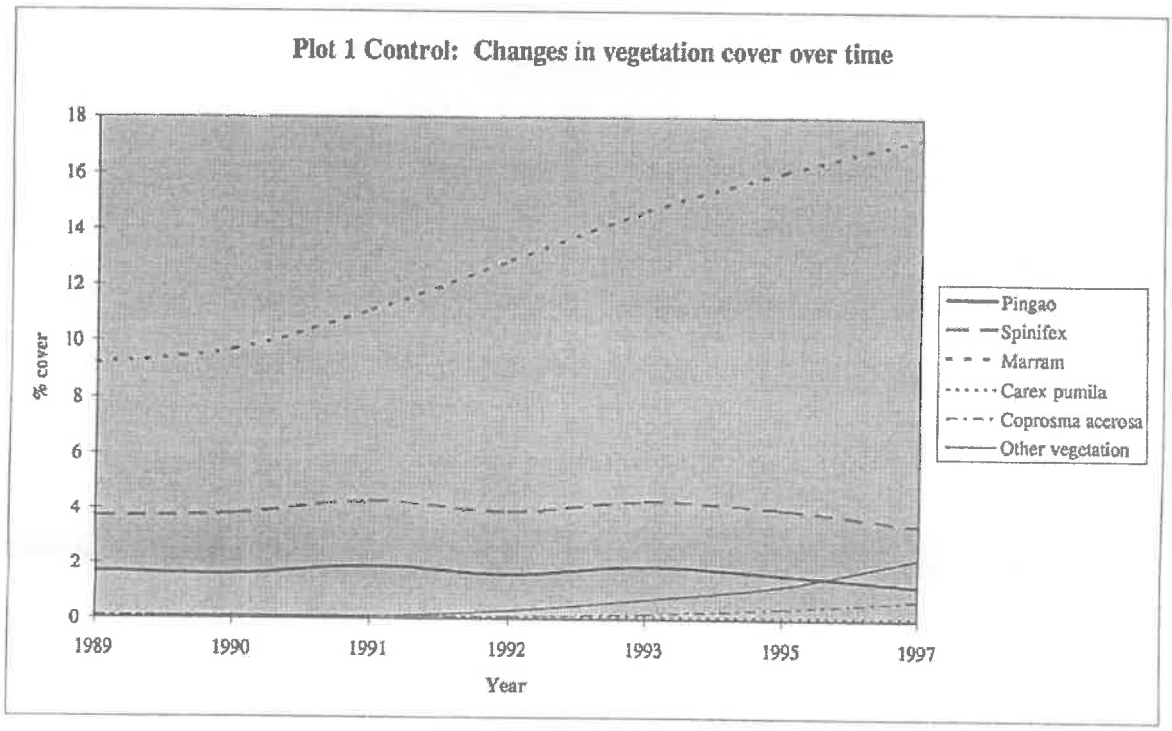


Figure 7. Changes in vegetation cover, control, Plot 1.

(the main big animals on the dunes) slowed the increase outside somewhat. An overall increase in spinifex within the big exclosure compared with a decline outside supports this explanation. Cattle and sheep were seen browsing both marram and spinifex.

Within the rabbit exclosure, the greatest part of the vegetation increase was contributed by a burgeoning of marram, greater in magnitude than elsewhere. However, there were comparable increases in spinifex and *Coprosma acerosa* as well. All the other vegetation increased slightly. From this it is possible to conclude that rabbits are major browsers of marram, spinifex and *Coprosma acerosa* at Ocean Beach and that they eat other plants also, though to a lesser extent. Observations in the field bear this out.

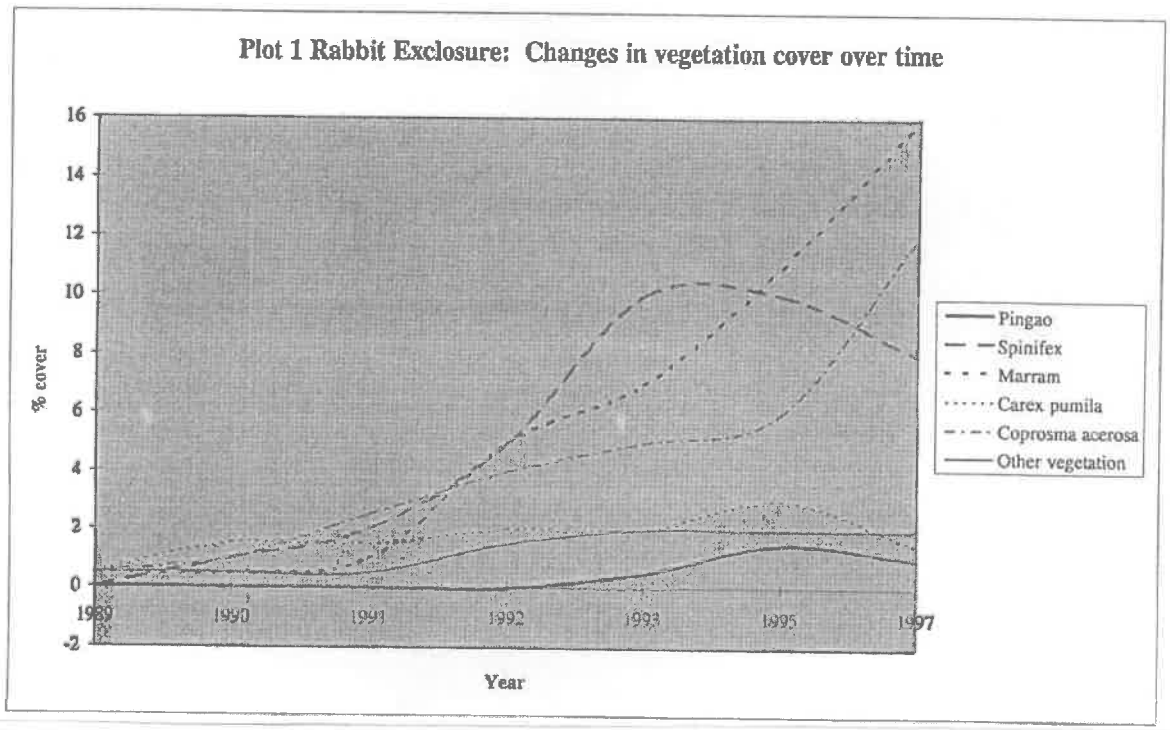


Figure 8. Changes in vegetation cover, rabbit exclosure, Plot 1.

4.1.2 Pingao

Because of a concern for pingao (Figure 24) at Ocean Beach, it was the subject of a particular focus. Living tufts of adult plants within the plot were counted at each measurement. So too were seedlings. The tuft counts show a trend of increase followed by decrease in all situations tested (Figure 9). This requires an explanation independent of browse. The obvious one is weed competition. I think it is necessary to look no further than that from marram grass, which increased dramatically in each situation, the decline in pingao corresponding to the burgeoning of the marram. The two plants overlapped in each place, the marram progressively invading the pingao's space.

The fact that the pingao increased at all, and did so most markedly in the control plot, needs another explanation. This happened I think because fresh sand was blown into the plot area, providing "new ground" for the pingao to

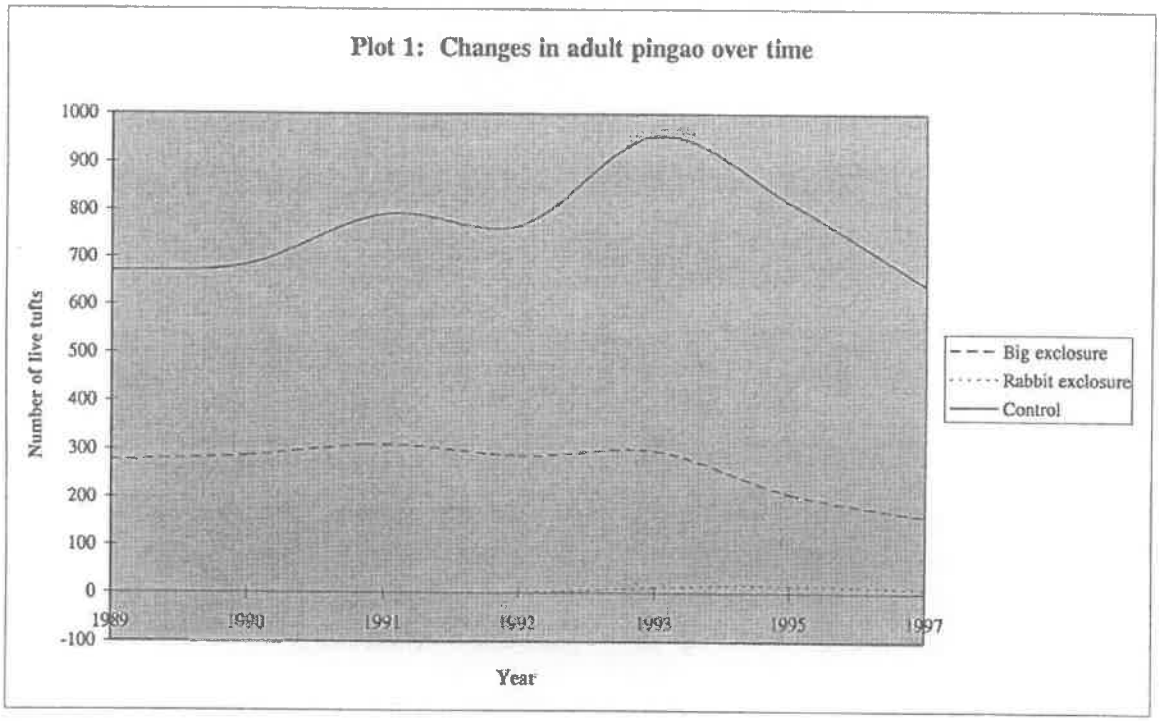


Figure 9. Changes in adult pingao in Plot 1 over time.

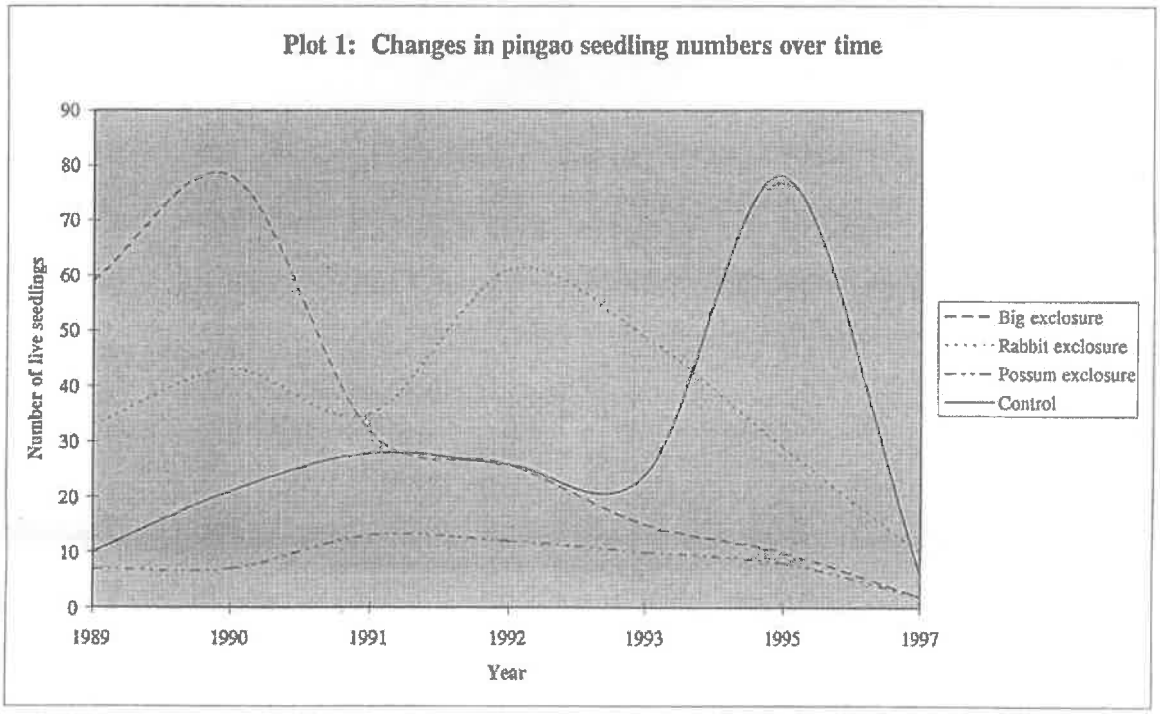


Figure 10. Changes in pingao seedling numbers in Plot 1 over time.

travel into and an injection of substrate and nutrients as a stimulus to growth. Unfortunately for the pingao, these conditions also encouraged the marram grass, which then began winning out. Over the next decade, unless there is some intervention, I would expect the marram to progressively dominate the pingao on the study site. The adult pingao will only persist on the newly drifted sand.

The pattern in the numbers of pingao seedlings (Figure 10) is fascinating. The trends with time scarcely correspond, except for those within both the rabbit exclosure and the possum exclosure, in which there was an increase followed by a substantial decline after 1992. In these two exclosures, the seedling densities were much higher than in the larger plots. They were initially located where they were for that reason, but the survival rates for their seedlings were also much higher. The figures alone suggest that rabbits, far more than possums, are responsible for preventing pingao seedlings persisting and maturing into adulthood at Ocean Beach. The visual confirmation of this was overwhelming. Seedlings alongside the rabbit exclosure were decimated by rabbits (Figure 25), whereas those a few centimetres away but protected from rabbits (but not possums) were unscathed and grew rapidly into adult plants (itself a contributor to the decline in the number of seedlings present!). Although even heavily browsed seedlings did recover, they were set back severely. Repeated browsing killed them.

The peaks in the graphs of the numbers of seedlings in the big exclosure, rabbit exclosure and control indicate "flushes" of seedlings that appeared for a while and were gone soon after. This was clearly not solely the result of rabbit browsing. Pingao seedlings are initially tiny things with a single fine leaf. They are very vulnerable and their environment is a harsh one (Figure 26). If they fail to send their roots down quickly enough to where the sand is moist they are doomed. If they get buried by drifting sand or undermined by wind deflation they are unlikely to survive for long. They also suffer from competition for moisture, nutrients and light from other plants. The best sites for them to germinate and grow are dune hollows or flats that are just too dry for other vegetation but provide sufficient stability and moisture for the seedlings to persist. So for most of the new seedlings that appear, often as a delicate green haze in a patch in the dunes, their future is curtailed by largely natural processes. This conclusion is supported by the fact that the seedling numbers declined overall in every situation. However, I believe that rabbit browsing is responsible for almost entirely preventing pingao seedlings being recruited into the adult population on the Ocean Beach dunes.

Adult pingao was seen to be relatively resistant to rabbit browse, although fresh new growth on runners was frequently browsed very hard (Figure 25). Sheep, horses, goats and cattle were all recorded browsing adult pingao (rarely seedlings, which I presume are too small to be targeted). Of them, cattle were by far the most damaging (Figure 27). They chew the leaves into a fibrous mass, then lift their heads, still chewing, which rips whole stem sections out of the sand and either breaks them off or leaves their roots exposed. Their great oafish hooves are capable of considerable damage to pingao runners too. Possums, although frequenting the du nes, were detected browsing pingao very rarely. I suspect their impact on the dune vegetation is relatively minor and that they seek out mainly pasture grasses and leguminous herbs.

Hares were present, but in such low numbers I could get no sense of their impact.

Physical damage to both adult and seedling pingao by off-road machines (quads, trail bikes and 4WD vehicles) was observed at Ocean Beach (Figure 28). The adult runners on dune faces were most badly affected, being frequently broken or ripped out. Flower heads were often flattened when run over. In total, the impact of these machines on the pingao during the study was much less than that of cattle and rabbits, but it was severe enough locally to cause the demise of plants in marginal situations and to set off episodes of destructive wind erosion through disturbance.

Wind appeared to have a substantial influence on pingao during the study. The photopoints showed this best (Figure 29). Whole areas of apparently healthy adult pingao progressively lost vigour and crumbled, eventually dying and being blown away. I believe that this is largely a natural process, and that pingao is a plant that goes with the flow of the sand on dunes, but that wind isn't the only factor. Pingao's healthiest new growth is invariably on new-built sand. Once it is well established as a clump or patch, the sand it clasps becomes relatively stable. Presumably the pingao progressively extracts the nutrients and moisture it requires, growing until the limits to the capacity of that bit of the dune to sustain it are reached. Then it loses thrift and dies back. Meanwhile, at its extremities the pingao flourishes, so long as there is new sand to colonise. Thus individual pingao plants move around the dunes according to conditions. It is possible therefore that some of the plants on the dunes are truly ancient - as old as any plants on earth.

The final influence on pingao that was observed during the study was that of competition. The main potential competitors were spinifex and (as already mentioned) marram grass, since they all occupied much the same niche.

Spinifex was found growing with pingao in many places. In each case the pingao continued to thrive for years, as did the spinifex. Spinifex was documented several times sending runners into pingao clumps. Again, both pingao and spinifex remained healthy.

By contrast, wherever marram grass and pingao occupied the same space (Figure 30) the pingao lost vigour and died back. The graphs in Figures 6-8 illustrate the effect on a larger scale as the marram has burgeoned and the pingao has declined. This is an interaction that has been documented elsewhere (Partridge 1991). The marram is considered to outcompete the pingao for available moisture; possibly also nutrients. There is no doubt in my mind that marram grass is a very serious weed of the Ocean Beach dune system.

Other plants (notably *Coprosma acerosa*, hare's tail, various pasture grasses, rosette plants and leguminous herbs) certainly grew with pingao in the study area. They were almost invariably among mature stems and old roots of adult pingao that had begun to decline for the reasons described earlier as a consequence of the maturing process. I found no evidence of significant competition from these other plants: they were simply taking advantage of the relative stability provided by the old pingao.

4.1.3 Spinifex

Not so spectacular as pingao, spinifex (Figure 31) is the quiet native sandbinding expert, so to speak, running about and clothing the naked sand with great ease.

The graph of changes (Figure 11) strongly suggests that spinifex is quite palatable to browsing mammals and is adversely affected by them. The basic evidence is that spinifex increased overall in both exclosures, whilst suffering a slight decline in the control plot. This is backed up by observations that were made of browsing of both adults and seedlings by domestic stock, goats and rabbits. Figures 6-8 illustrate a latter decline in spinifex, echoing that of pingao, that coincided with the rapid increase in marram grass - hence the conclusion that marram is a serious competitor with spinifex and therefore a weed in the Ocean Beach context.

Spinifex demonstrated a remarkable ability to take advantage of the changing patterns of sand in the dune system, even more so than pingao. Its "tumbleweed" seedhead that can blow all around the dunes is the obvious example of that. Less obvious is its stunning growth rates. I recorded runners extending more than five metres in just a year: growth to make any plant opportunist proud. What this meant was that spinifex could very rapidly colonise new sand nearby, retreat from unfavourable conditions or survive even deep inundation. The only conditions it couldn't handle well were those of major sand deflation by wind and competition with marram grass. It was less prone to vehicle and cattle damage than pingao, and better able to recover after such damage.

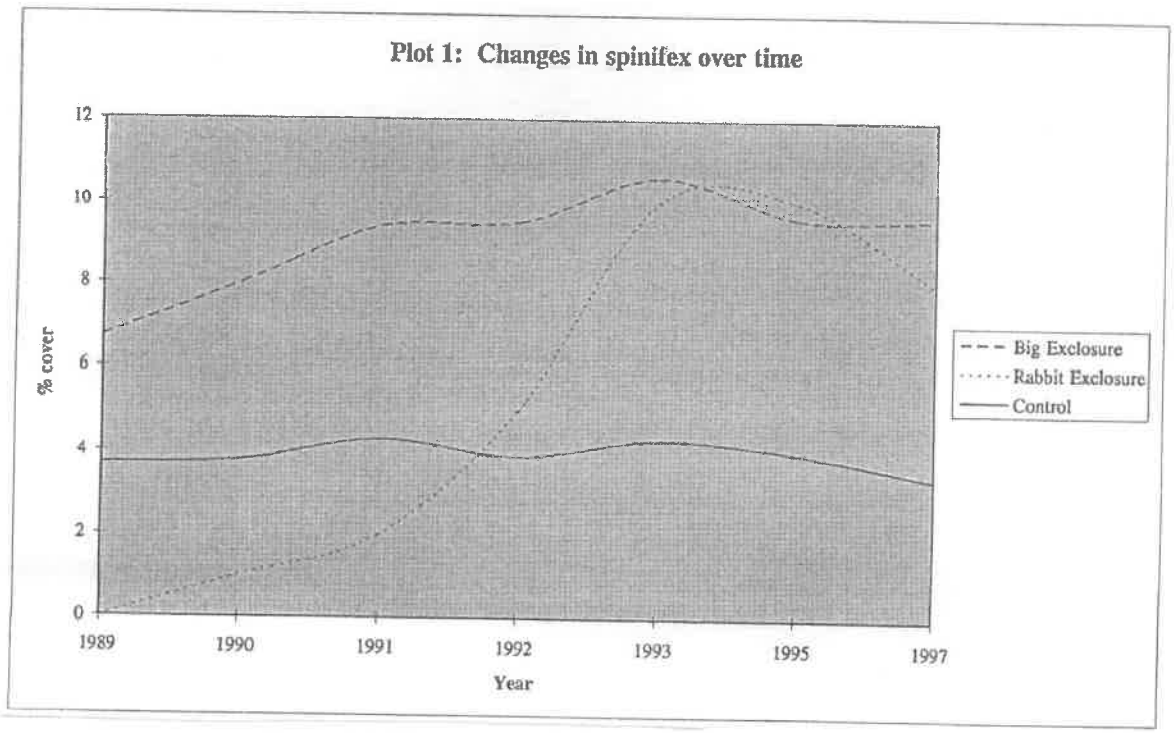


Figure 11. Changes in spinifex over time, Plot 1.

4.1.4 Marram grass

The finger has already been pointed at marram grass (Figure 32) as a serious weed of the Ocean Beach dunes. That is because this study has documented its adverse impact on the native vegetation. Figures 12 & 33 show how the percentage cover of marram increased markedly in all three situations in Plot 1. Within the rabbit exclosure there was a veritable explosion of marram, a 32-fold increase in eight years. Within the big exclosure there was an almost four-fold increase in the same time. Within the control, the increase was a mere near-doubling. It is tempting to conclude that the relative differences are due solely to browsing: that rabbits kept the marram in check to a considerable degree and that the larger browsers to a lesser degree. I believe there is truth in that conclusion, supported by observations of marram being browsed by these animals. However, there is also another factor.

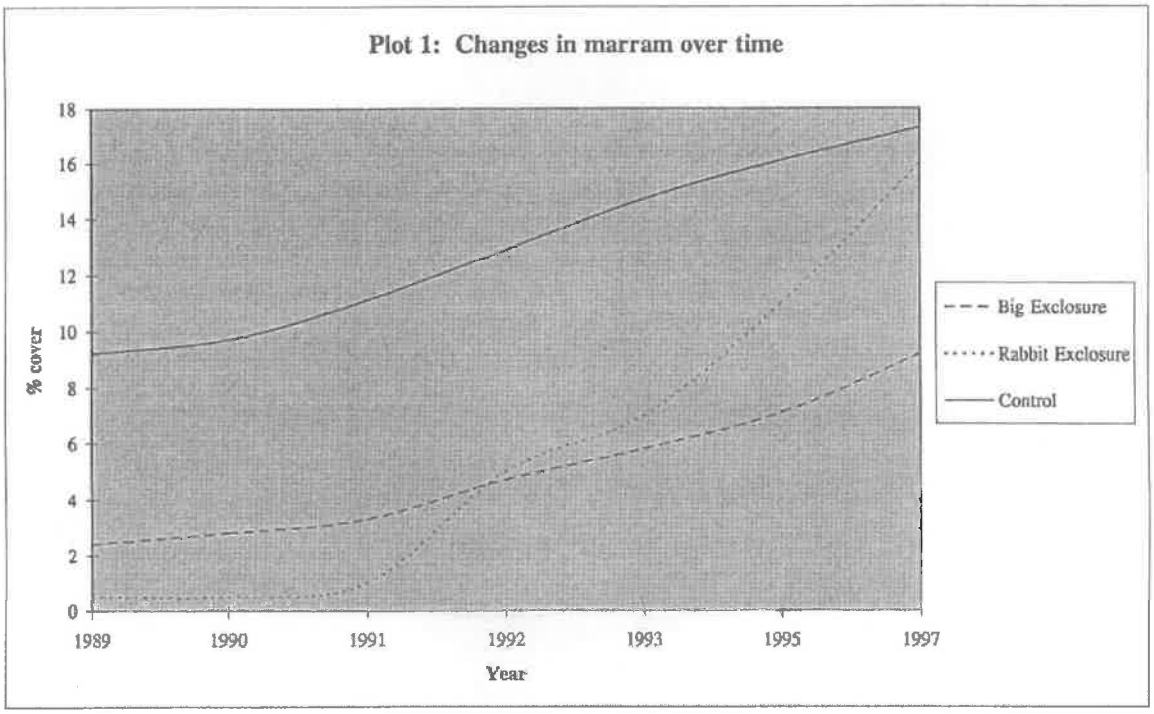


Figure 12. Changes in marram over time, Plot 1.

Marram grass is still invading the Ocean Beach system. Like the native sandbinders it thrives best in newly deposited sand. Unlike them it stabilises sand to a far greater degree and can handle a fair amount of stability, which is why it is a problem for the native plants that rely on sand flow but is beloved by those to whom sand flow is a worry. Once marram stabilises a site it does itself out of new sand to colonise, and merely sits and thickens. The inevitable medium-term result, if there is no intervention, is a sand dune system almost entirely covered in marram. In the longer term, the marram is likely to be replaced by self-sown shrubs, small trees, scramblers, grasses, rushes, sedges and other non-dune plants, ending up with a weedy vegetation that has lost its native duneland character.

In parts of Plot 1, this process is already well advanced. Marram is firmly established and changes little from year to year except to spread around its

fringes into fresh sand. There was more of the control plot like this at the beginning of the study than in the exclosures: in fact there was very little mature marram in the rabbit exclosure. So what Figure 12 shows are three different invasion stages: explosive early colonisation within the rabbit exclosure, expansion and thickening within the big exclosure, and consolidation within the control.

Marram grass, a European species, has been deliberately introduced to areas of mobile sand around the world in order to stabilise them (Buell et al. 1995). It is now recognised that much of this has been misguided, and marram is now considered a major global weed because of what it does to dune systems. It displaces native sand specialist plants and ossifies dunes. The coastal energy of nature - wind and sea - has to go somewhere. What usually happens is that abrupt sand cliffs, very prone to dramatic local erosion, appear at the foredunes, and deep unstoppable wind scoops and chasms occur within the dunes. That, the loss of pingao, spinifex and other native sand plants, and the development of the weedy vegetation described above, will be the fate of the Ocean Beach dunes unless the marram is controlled.

4.1.5 *Carex pumila*

Carex pumila is a small native sand sedge, usually encountered in damp (not wet) dune hollows but seemingly equally at home on drier sites. It is quite common on the Ocean Beach dunes, but to most visitors it would go unnoticed. In Plot 1 it was a minor component of the vegetation, forming less than 1% of the cover in both the big exclosure and the control. Within the rabbit exclosure it increased six-fold, to a peak of 3% cover in 1995 (Figure 13). Its subsequent decline, like that in the big exclosure, was probably largely caused by the increase in marram grass. Rabbit browse of *Carex pumila* was observed in both the big exclosure and control.

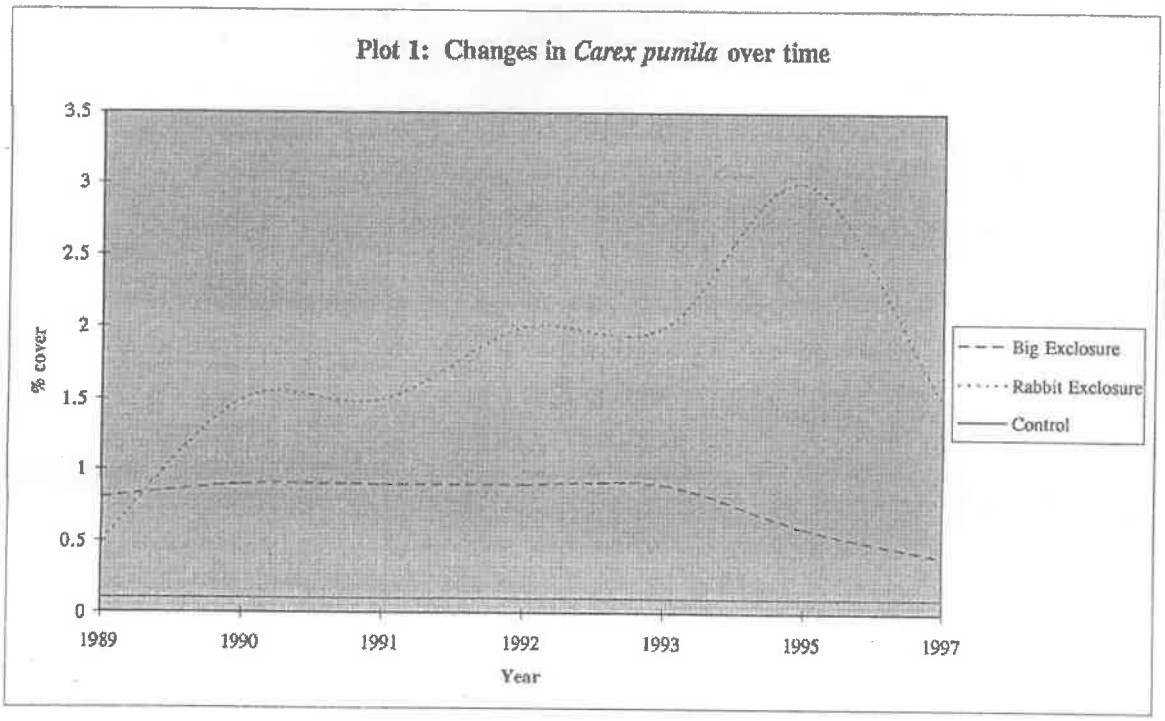


Figure 13. Changes in *Carex pumila* over time in Plot 1.

4.1.6 Coprosma acerosa

Coprosma acerosa is one of the few woody plants to make a successful living on New Zealand sand dunes. It is quite versatile, also tolerating flood-prone river banks, arid river beds, cliffs and hillsides from the coast to montane zones. Superficially it looks like a sprawling entanglement of rusty wire mesh, but at close quarters it has a genuine beauty of specialised adaptation in its orange stems, tiny narrow leaves and pale blue teardrop fruit.

In the study of Plot 1, *Coprosma acerosa* was the only native plant to increase at the same time as the marram grass. Within the rabbit exclosu re it positively skyrocketed, increasing 24-fold in eight years (Figure 14), whereas it showed lesser increases elsewhere and was far less abundant. The obvious explanation is that it was being seriously impeded in growth by rabbits. This was confirmed by direct observation of *Coprosma acerosa* being browsed very hard by the rodents, particularly when young (Figure 34).

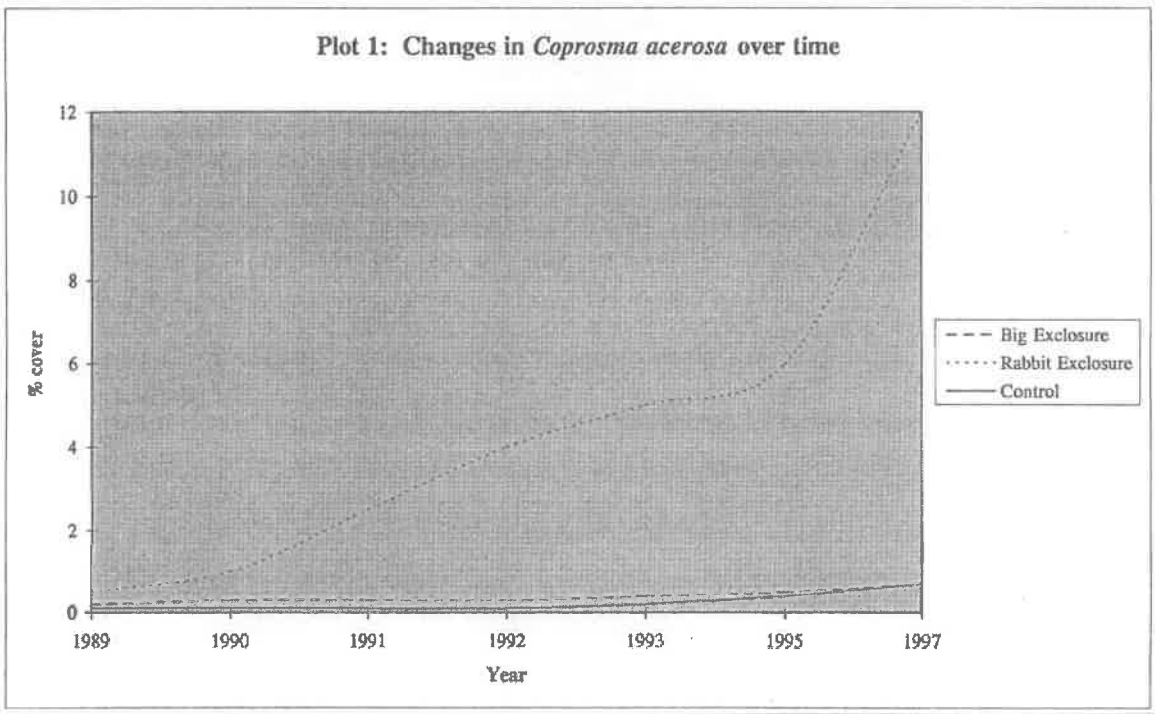


Figure 14. Changes in *Coprosma acerosa* over time, Plot 1.

4.1.7 Other vegetation

Vegetation in Plot 1, other than the plants dealt with in detail, included the natives tauhinu, knobby clubrush and shore bindweed *(Calystegia soldanella)*. None was very common. More abundant were various grasses, rosette plants ("flatweeds"), thistles and leguminous herbs, originating from the adjacent pastures, and vagrant plants such as evening primrose *(Oenothera biennis)*. In total, though, all this vegetation amounted to a relatively small proportion of the total plant cover and biomass.

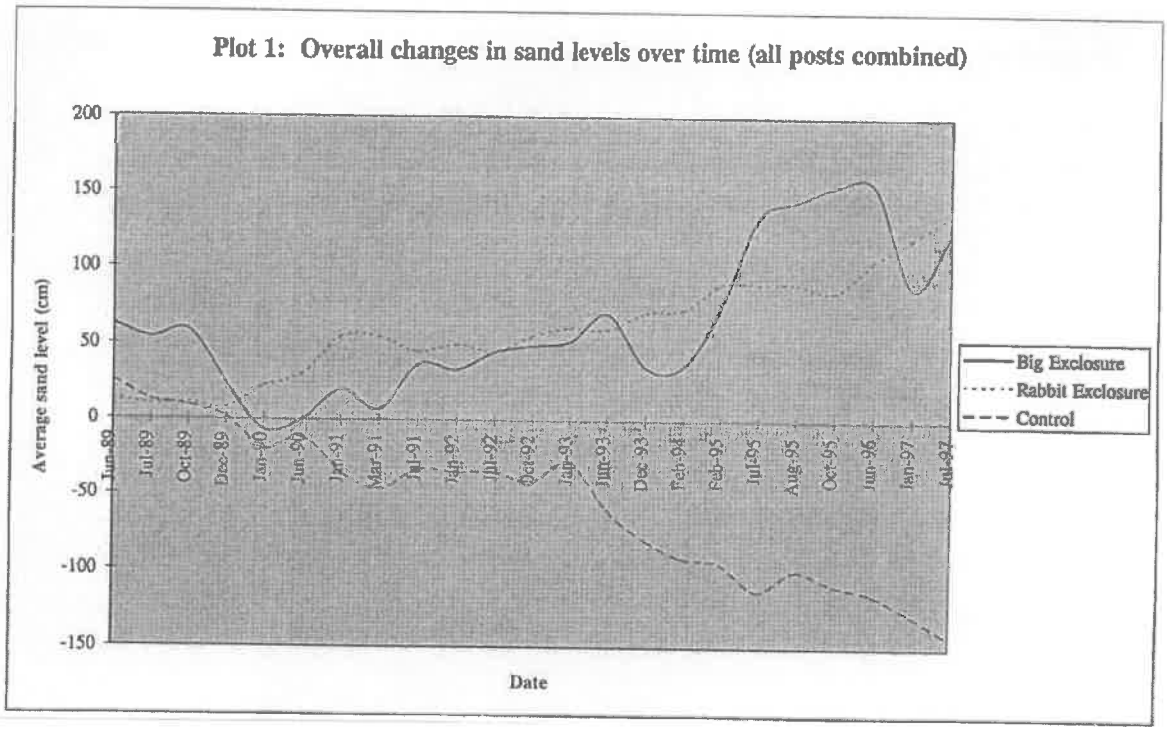


Figure 16. Overall changes in sand levels over time, Plot 1.

Figures 17-19 & 35 track the more complex processes happening in the dunes on a smaller scale. Within the big exclosure (Figure 17), there was a massive ongoing build-up of sand in the southwestern corner, that required three extensions of the posts and netting there. Meanwhile, in other places, there was either a much slower steady build-up or a steady deflation. In some places build-up alternated with deflation. In several instances adjacent posts showed opposite trends.

Within the control (Figure 18), the pattern was more splayed. At one post on the eastern side the sand steadily built over time. In most other places it deflated to varying degrees (most rapidly in the south), whilst in the southwestern corner it initially deflated then proceeded to build.

Within the rabbit exclosure (Figure 19) there was a considerable sand build-up at three of the four corners. At the other corner (the northwest) there was an initial rapid build-up followed by a steady deflation of that built sand.

What these graphs symbolise is the dynamic and subtle nature of sand dunes. So long as there is sand to be blown and wind to blow it, the dunes will be forever changing their shape. Prevailing winds (in this case westerlies) will shape the dune system in a general direction. However, individual storm events can make just as much impact, plucking sand, driving it, etching and scouring. They may reverse in a matter of hours months of steady directional progress, or destroy in a singe outburst the impression of stability in a place. What happens at any one site depends on what obstacles exist, how they are shaped and what has happened there previously. This study has revealed in many ways that this is how the Ocean Beach system works. The sand level measurements have put a handle on it.

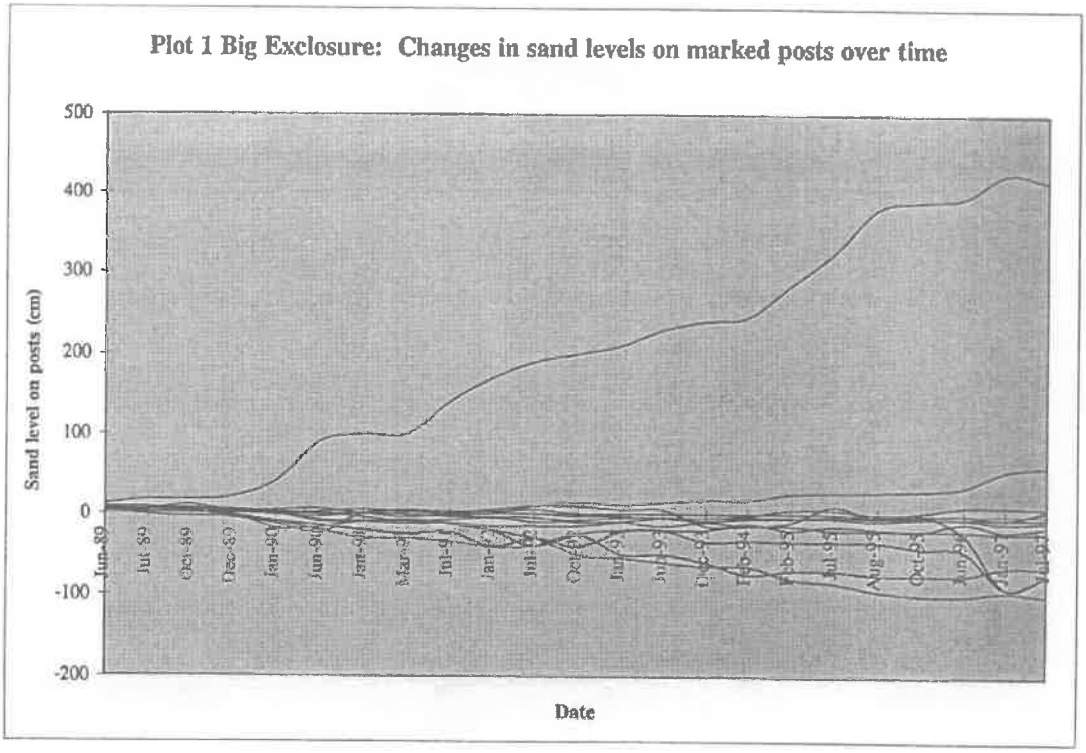


Figure 17. Changes in sand levels over time in the big exclosure, Plot 1.

I think that what I have observed at Plot 1 is the movement of the same sand around the system. It has progressively deflated from unvegetated broad hollows and built at the faces of mobile dunes and where there are solid barriers. Two such solid barriers are the close-mesh rabbit netting and areas of mature marram grass. I am sure that such barriers are bad for the wild spirit of the dunes. They prevent the natural flow of sand around the system, making conditions less favourable for the native plants that are adapted to go with that flow. This is another aspect of the litany against marram.

4.2 PLOT 2

Plot 2 examined a totally different circumstance from that of Plot 1. It was a mere 10 m x 10 m square on a stable heavily vegetated dune flat. The unusual thing was that in 1989 adult pingao was flourishing on the site, although browsed by cattle, sheep and goats. I put in the plot to follow the fate of the pingao. I did not expect it to be able to persist on such a site.

Sure enough, the pingao declined virtually to extinction within six years (Figures 20, 21 & 3C). For the first year of the study it expanded, but its ascent was brief and from then on it dwindled away. I think there is no great mystery to what happened.

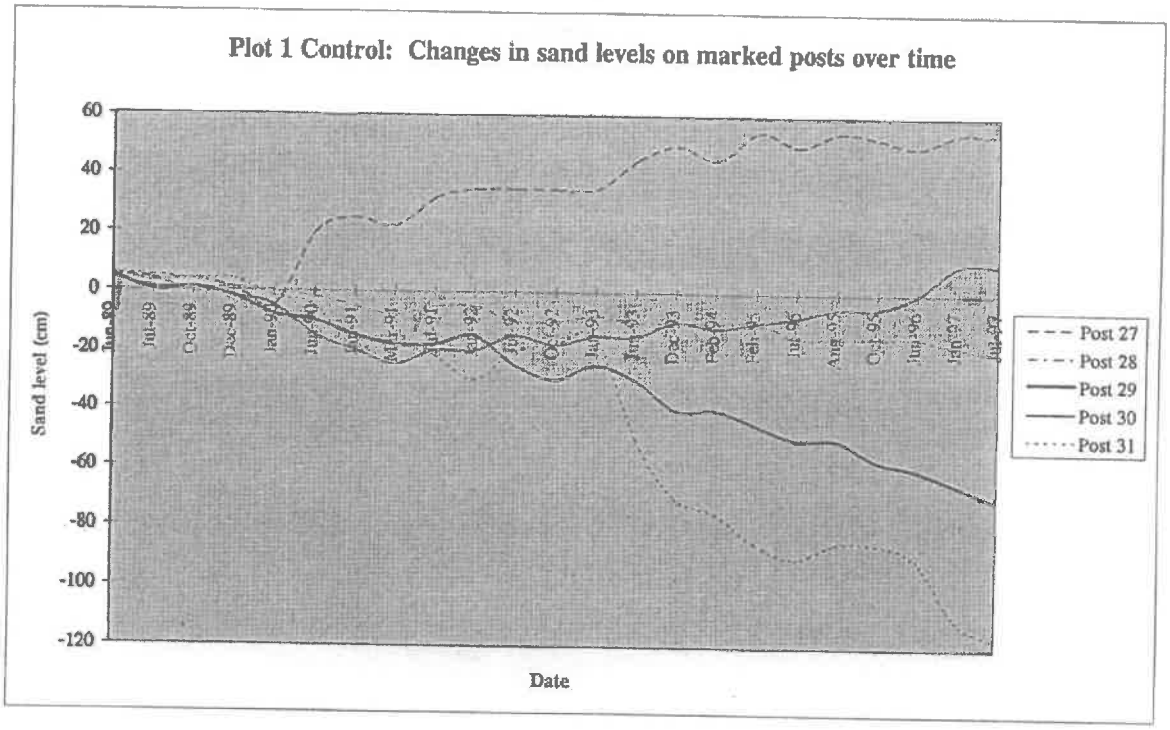


Figure 18. Changes in sand levels over time in the control, Plot 1.

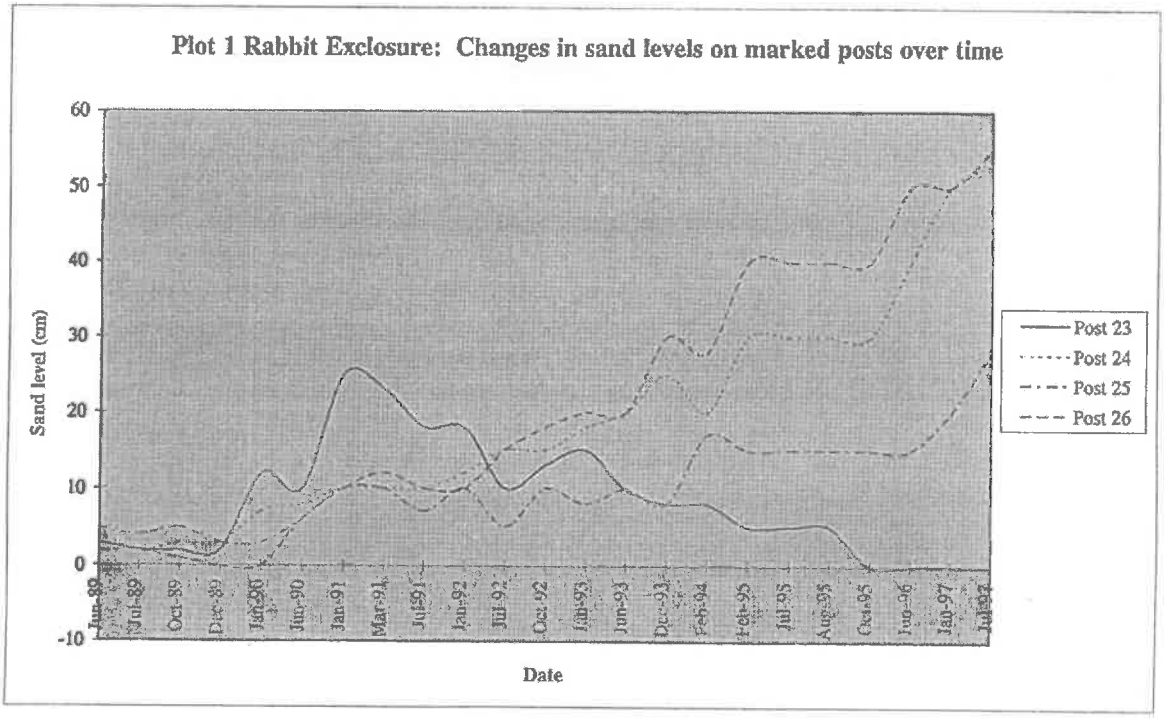


Figure 19. Changes in sand levels over time in the rabbit exclosure, Plot 1.

With the exception of taullinu and knobby clubrush, both at home on the more stable rear dunes and quite long-lived, these plants were transient. They would appear, last for weeks or months on a site, then disappear. They were usually defeated by being inundated or undermined by blown sand, sometimes by seasonal drought and occasionally by rabbits. The annuals and biennials came and went according to their allotted life spans. Most prominent among these was King Island melilot *(Melilotus indicus),* a lush leguminous annual herb that suddenly burgeoned on the dunes in the latter years of the study.

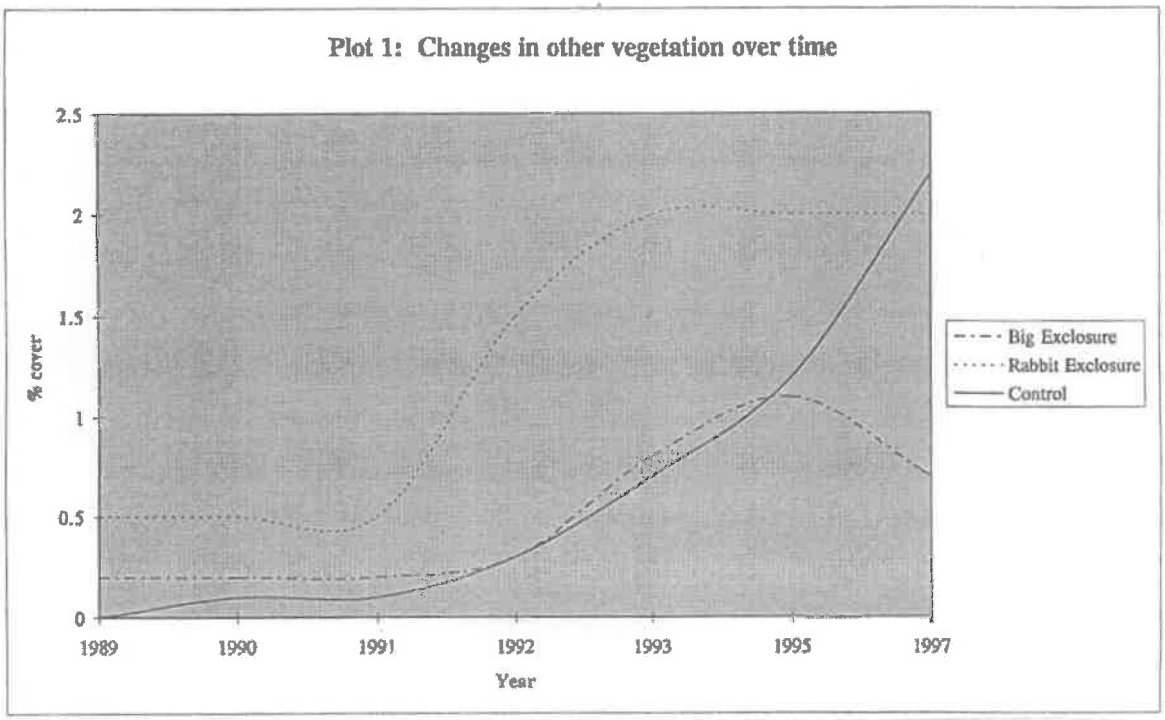


Figure 15. Changes in other vegetation over time in Plot 1.

Figure 15 shows that in all three monitored situations in Plot 1 the total amount of other vegetation increased substantially over time. Within the big exclosure there was a decline latterly and within the rabbit exclosure a levelling-off. Within the control, however, the percentage cover kept rising rapidly. I think the explanation lies in a combination of browsing, particularly by rabbits, and of gradually increasing stabilisation of this part of the dune system by vegetation, led by marram grass. The rabbits held the vegetation back somewhat, whilst the marram increasingly squeezed it, especially within the exclosures.

4.1.8 Sand levels

Figures 16-19 illustrate the trends of the levels of sand on marked posts in Plot 1. In Figure 16 all data for each of the study situations is averaged. What is indicated is a slight sand build-up within the big exclosure (an average of 60 cm over eight years), although the fluctuations were marked,a steady build-up (over 120 cm) within the rabbit exclosure, and a steady deflation (170 cm) within the control.

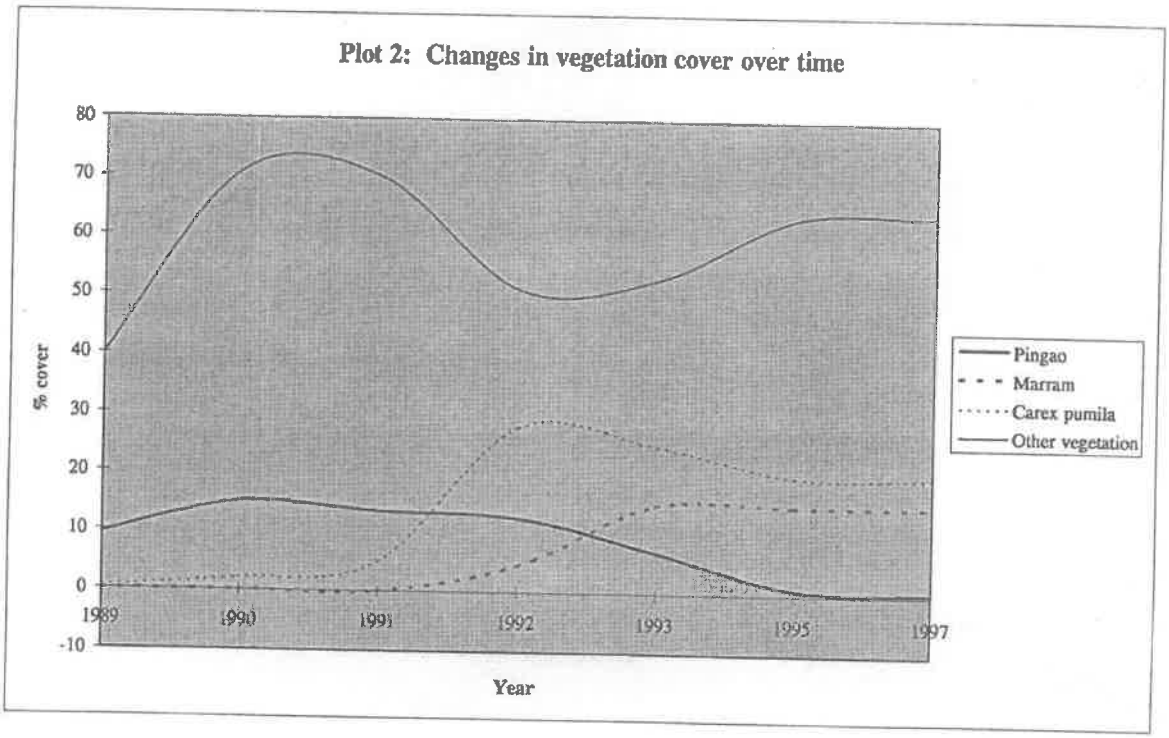


Figure 20. Changes in vegetation cover over time, Plot 2.

Prior to the beginning of the study the dunes were used to winter farm stock, especially cattle, and there were many feral goats around. These animals between them kept the more edible vegetation on the dunes down, diminishing competition for the less palatable pingao and permitting plenty of sand movement. By the time the study had begun, Haupouri Station had lessened its use of the dunes by stock (partly as a result of my interest) and the goats had been removed. That allowed the initial burst of growth in the pingao, unfettered by browse and competition. From then on, though, other vegetation proliferated on the site and the pingao simply couldn't stand the competition for moisture, nutrients and space. Substrate conditions could have been changed by the vegetation build-up as well, allowing the pingao to be exposed to soil pathogens it wasn't accustomed to. The occasional spell of browsing and trampling by cattle didn't help either, and a destructive bout in 1991 may have helped precipitate the decline, but it was the other vegetation that was the ultimate cause of the demise of the pingao on this site.

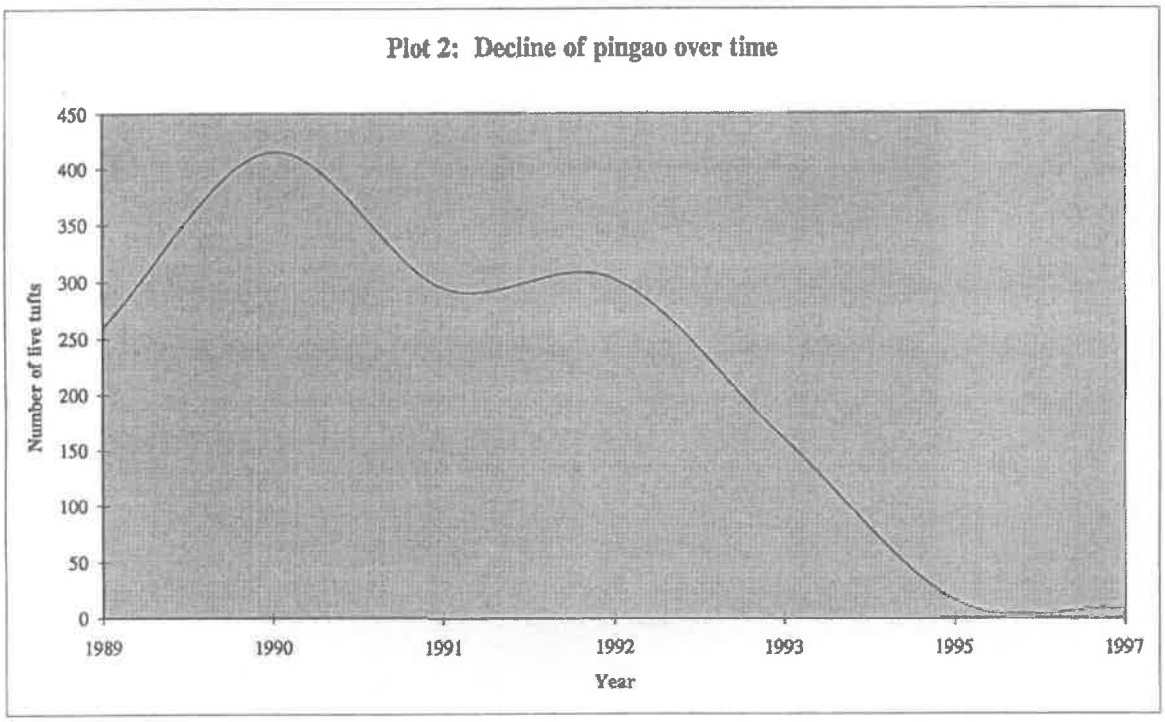


Figure 21. Decline of pingao over time, Plot 2.

The other vegetation consisted of marram grass, *Carex pumila,* hare's tail, knobby clubrush, shore bindweed and a plethora of pasture grasses and herbs. Although the marram invaded the plot during the study, by the time it did so the pingao was already on its way out, so it can't take all the blame. *Carex pumila* proliferated after 1991, probably as a result of lessened browsing, and undoubtedly helped contribute to the competition for the pingao. Its own subsequent decline suggests that it, too, suffered from competition. That competition came from the hare's tail, pasture grasses, rosette plants and leguminous herbs that burgeoned on the site in 1990-91, got knocked back by sheep in 1992-93 and built up again. Knobby clubrush and shore bindweed appeared to be incidental players in the bigger drama.

4.3 PLOT 3

Plot 3 was another little plot, a five metre wide strip of foredune. I set it up to observe the interplay of pingao and spinifex right where they met the sea.

Figure 22 shows that all vegetation in the plot expanded during the study, but the expansion was not linear. Pingao increased steadily until 1995 by seaward expansion, but was knocked back by stormy seas in 1997 that chopped off its seaward runners (Figure 37). The same happened to spinifex, twice: because it extended further seawards earlier than the pingao it was also chopped off in 1992. The other vegetation, made up of small amounts of knobby clubrush, hare's tail, various pasture grasses, rosette plants, sea rocket *(Cakile maritima)* and King Island melilot, waxed and waned largely independent of the wave effect. Fluctuation in the amount of the melilot accounted for most of the change.

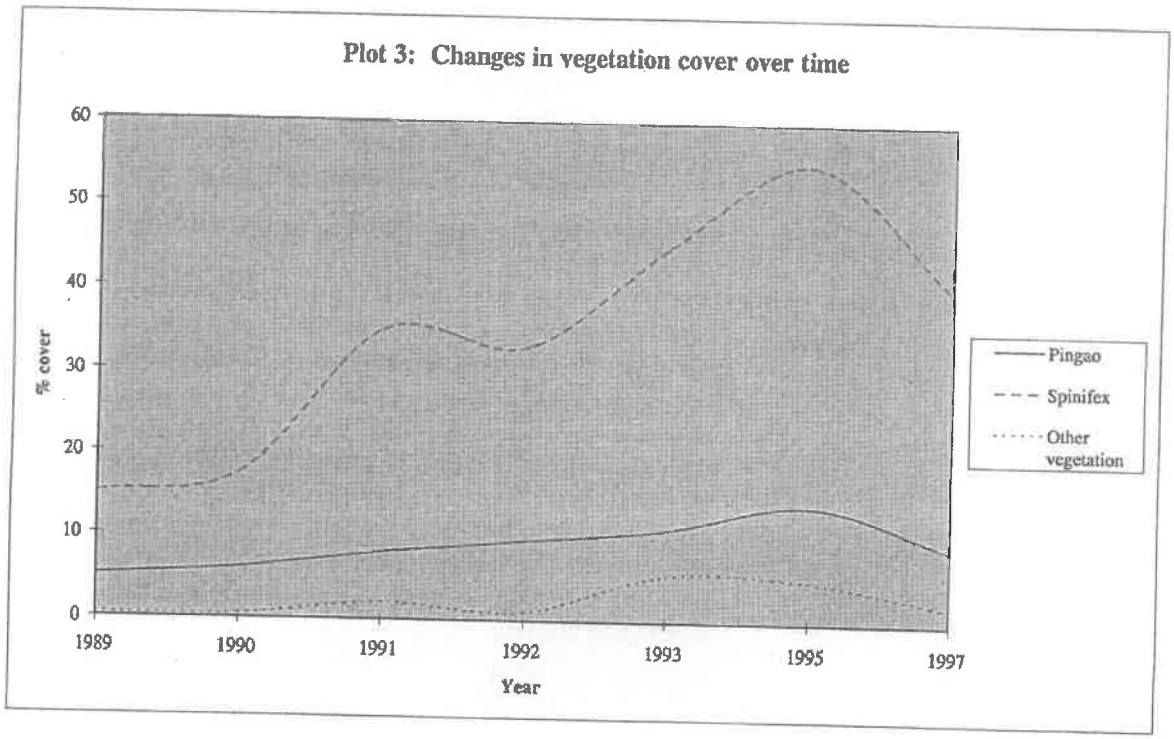


Figure 22. Changes in vegetation cover over time, Plot 3.

On this site, no browsing by mammals was ever observed. The plot therefore simply bore witness to the great meeting between land and sea, between Tane Maliuta and Tangaroa. Pingao, nga tukemata o Tane (the eyebrows of Tane, plucked out and offered to the sea god as a gesture of peace) was flung back on the shore as in the beginning of time (Herbert and Oliphant 1991). So too was spinifex, that stalwart and unsurpassed guardian and healer of this country's coastal sands. They were kept firmly in their place.

5. Conclusions and management recommendations

The sand dunes of Ocean Beach are full of drama. The whole system has regional and national significance, and is worthy of a high level of protection. This contradicts the ranking assigned by Partridge (1992) in a national dune and beach inventory. Partridge rated Ocean Beach as Priority 2-3, based on skeletal information. Using his criteria, I rate it Priority 1-2, in other words among the finest in the country. Without protection, the remaining natural and cultural features of Ocean Beach will pass rapidly into oblivion. The following is a breakdown of my findings and their implications.

1. This research has shown a trend in all sites examined of increasing vegetation cover on the Ocean Beach dunes. Most of this was accounted for by a bulking up and spread of marram grass. It can be partly attrib-

uted to a lessening of browse impact from domestic stock and feral goats, somewhat offset by an increase in rabbit browse. It is unlikely to be the result of climatic change because the more settled conditions required haven't actually occurred. Mostly it is consistent with basic patterns of weed invasion.

2. The increase in weediness observed in the study sites is happening throughout the dune system. It is at the expense of native sand plants, particularly pingao and spinifex. Marram grass is the most serious weed of the dunes and must be controlled if the native sand plants are to persist. Its rate of spread is such that the situation is now urgent. Pampas grass and self-sown pines are also spreading fast and should be checked before their control is a massive task. Willows and blackberry constitute lesser problems. Boxthorn (Lycium ferocissimum) may become a future problem unless checked.

3. *Coprosma acerosa* was the only native plant to increase at the same time and place as marram. Its relative health, despite severe rabbit browsing, is because it is able to take advantage of the increased sand stability created by the marram. In the long term, it too is likely to be swamped by introduced vegetation. *Carex pumila* is a "bit player" in the dune drama, an opportunist without malice.

4. Cattle are particularly damaging to pingao, through browsing, ripping up of runners and trampling. They and sheep browse and graze most of the other dune plants. Their impact and dung contribute substantially to the replacement of the native vegetation by introduced species. The Ocean Beach dune system needs a stock-proof rear fence to protect it. This need is also urgent.

5. Rabbits are the single greatest animal threat to the native dune vegetation, mainly through browsing seedlings and adolescent plants. Their control is essential for the health of the sandbinders in particular.

6. Possums and hares, though resident at Ocean Beach, make only minor impacts on the vegetation. Feral goats used to be quite damaging until they were eliminated: should they make a comeback they will need to be controlled again.

7. Offroad vehicles, mostly quads and trail bikes, are highly destructive to native sandbinders on dune faces. Their use at Ocean Beach has increased over the years until they are becoming a major conservation problem there. The dune system is too valuable and fragile to be used as a playground for these machines. Education and vigilance will be required to diminish their use sufficiently.

8. Pingao, Tane Mahuta's eyebrows and treasured gold of the traditional artisans, is indeed on the decline at Ocean Beach, as feared. The study showed an initial slight increase in adult Pingao cover as the result of lessened browse pressure, but that was quickly overtaken by a steady decline due to weed competition. Marram grass was the most serious competitor on mobile dunes. Invading pasture grasses and herbs, and

possibly their accompanying pathogens, killed off the pingao on a stable dune flat. Adult pingao loses vigour and dies naturally once it gathers enough stable sand around itself. Left to its own devices it will grow out into new sand, but the availability of such opportunities is being curtailed by weeds, browsing and vehicle damage. Finally, browsing by rabbits of pingao seedlings - ephemeral at the best of times - almost totally prevents the recruitment of new pingao genetic combinations into the dune population.

9. Spinifex is the unsung hero of the dune system, as surely as marram is the villain. It quietly goes about its business of binding the sand, but not fettering it, from the sea-plucked foredunes to the more stable rear dunes. It is beautifully adapted to life on the dunes, casting its seed to be tumbled in the wind looking for new sites and sending its runners out into new sand at remarkable speed. Spinifex and pingao readily coexist. Marram and browsing animals are threats to spinifex at Ocean Beach. Lucy Moore wrote of marram as "probably the most important sand plant of all" (Moore & Adams 1963), extolling its virtues as a sand stabiliser. I think the most important sand plant is spinifex, and if we treasure the wild nature of dunes the marram has to go. I am sure that Lucy would agree, were she alive today and able to look at the scene 35 years on.

10. Nothing illustrates the dynamic spirit of the dune system as well as the sand itself. This research has shown that there are substantial sand movements in the Ocean Beach system, driven by the energy of the wind. Sand ebbs and flows with prevailing winds and storms. Change can be gradual or abrupt, unidirectional or contrary. The shapes of the dunes depend on the obstacles to sand flow and their history. This is all natural and the native sand binders are adapted to it. Dunes are inherently dynamic (Cowie 1963, Ogle 1997). Stopping the flow of sand with solid barriers or plants like marram grass is inconsistent with conservation.

11. My whimsical study of a situation where pingao and spinifex grew down to the sea confirmed that these plants are firmly terrestrial, rejected by the marine environment. Nevertheless these children of Tane Mahuta will continue to court Tangaroa endlessly, dependent on the continued supply of fresh sand, salt and plankton.

12. The native fauna of the Ocean Beach dunes is already hugely diminished by the changes wrought by human settlement. Even before Europeans arrived, the big birds, seals and most reptiles had gone. Their traces, including those of moa, kakapo, petrels and tuatara, have been found in the middens. Many more delicate creatures will have disappeared without trace. A few birds, skinks and invertebrates are all that remain. They will only survive with help. What is needed is making sure the wild dune habitat remains, and competitor and predator control to make the habitat safer. The first thing to start with is a detailed survey of the invertebrates and their likely threats.

13. Ocean Beach has a long human history. Much evidence of that has seeped into the sand and remains there. Only if the dunes are cher-

ished will that evidence be protected. Cattle, self-sown pines, off-road vehicles and human fossicking are the greatest threats to the archaeological integrity of the dunes at present.

14. Partnership is the key to successful conservation management of the Ocean Beach dunes. The most obvious partnership is that between the two land custodians, Haupouri Station Trust and the Department of Conservation. The other main participants are the tangata whenua, Otarara Roopu Raranga, the Hastings District Council and the Hawkes Bay Regional Council. At Rangaiika on Summerlee Station, immediately to the north, many of the dune issues are identical to those at Ocean Beach. I suggest that the two land custodians of the Ocean Beach dunes get their heads together soon and work out a conservation strategy. They then consult the other participants, and if necessary set up a steering or advisory group to guide and oversee management. Otherwise, the situation will drift and the deterioration of the dunes will continue instead of being reversed.

15. The tasks essential for conservation management to be a success at Ocean Beach are:

- legal protection of the dunes;
- fencing to exclude domestic stock;
- weed control (marram grass, pines, pampas grass);
- rabbit control;
- predator control (rodents, mustelids, cats, hedgehogs);
- ecological monitoring and survey (vegetation plots, photopoints, invertebrate and lizard assessment);
- public education (dune ecology, fragility, threats, vehicle impact).

16. Simply sand? No way!

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7. Acknowledgements

Jody Stent and Atareta (Bana) Paul introduced me to Ocean Beach, drew my attention to the plight of the pingao and showed me what beautiful items pingao leaves were traditionally woven into. Thereby, they began this work. Haupouri Station Trust and successive farm managers granted access, allowed the study to proceed and showed continuing interest: without that support the research would have been impossible. Department of Conservation staff Ken Hunt, Alan Lee, Hans Rook, Charlie Janes, John Adams and John Ombler gave help and encouragement with the research from time to time. Most of the field work was done solo, but I had some splendid assistance from Sandra Anderson (Auckland), Finn and Site Scheele (Napier) and Angela Walls (Nelson). At the end, Department of Conservation scientists Chris Ward (Gisborne) and Chris Robertson (Wellington) organised the contract funding so the write-up could proceed.

I took various experts - in archaeology, history, geology, plant ecology, duneland restoration, weeds, creative arts, landscaping, birdlife, insects, fencing, journalism, etc. - with me to Ocean Beach over the years. Their insights helped give me a holistic picture of the place, and I am sure helped my interpretation of what I observed immensely.

To all, my sincere thanks.

8. Photographic appendix: (Figures 23-38)

Figure 23 Three elevated views of the Ocean Beach dune system, showing its billowing dunes, ephemeral wetlands in hollows and vegetation mosaic. Plot 1 is sited near the centre of each dune view.

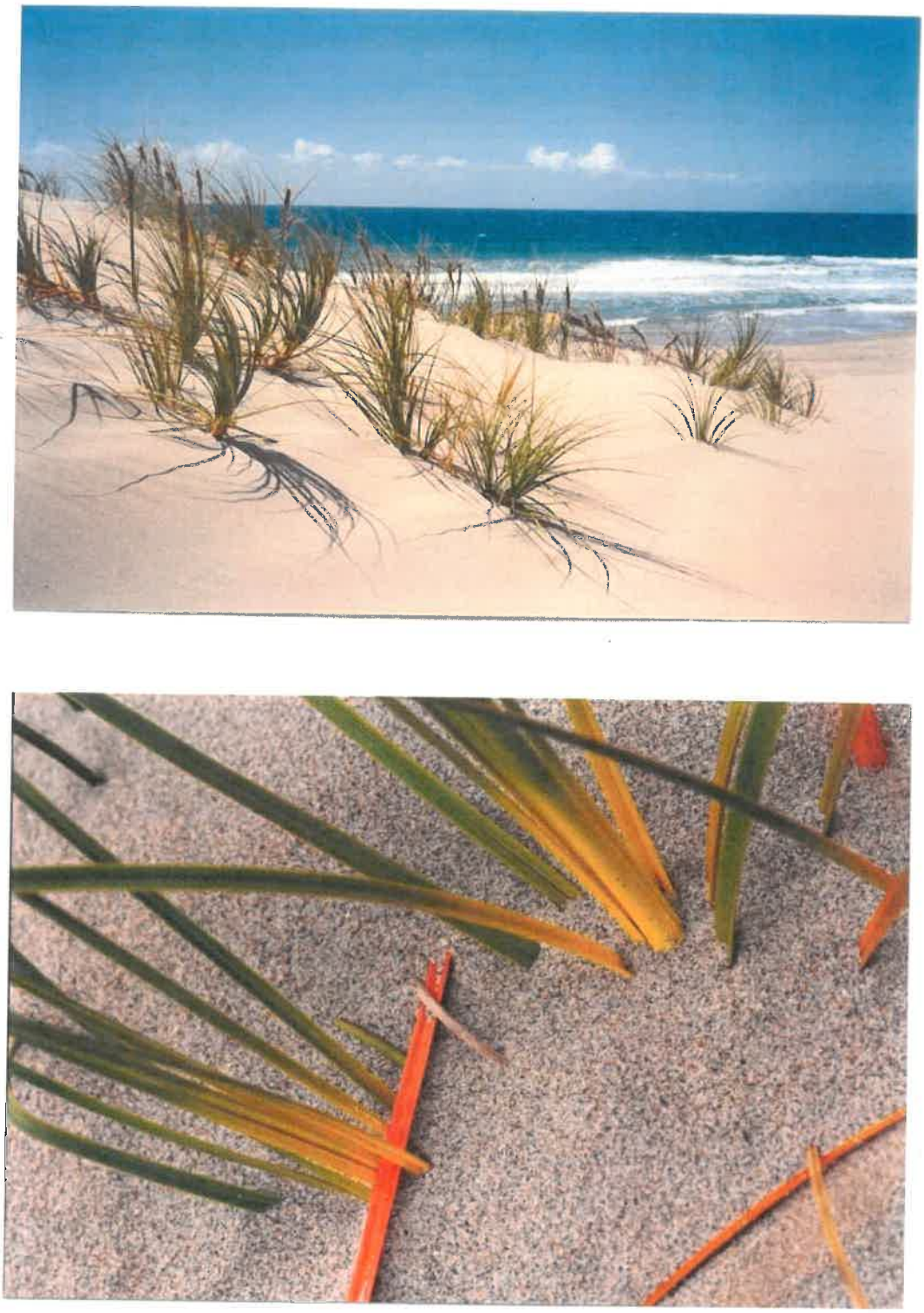

Figure 24 Top: pingao, nga tukemata o Tane, in seed on the Ocean Beach dunes. Bottom: winter colours of pingao.

Figure 25 Rabbit damage to pingao at Ocean Beach. Top: seedlings nipped back outside the rabbit exclosure, but untouched within. The cage is a possum exclosure. Bottom: adult runner browsed by rabbits. Middle: seedling being excavated.

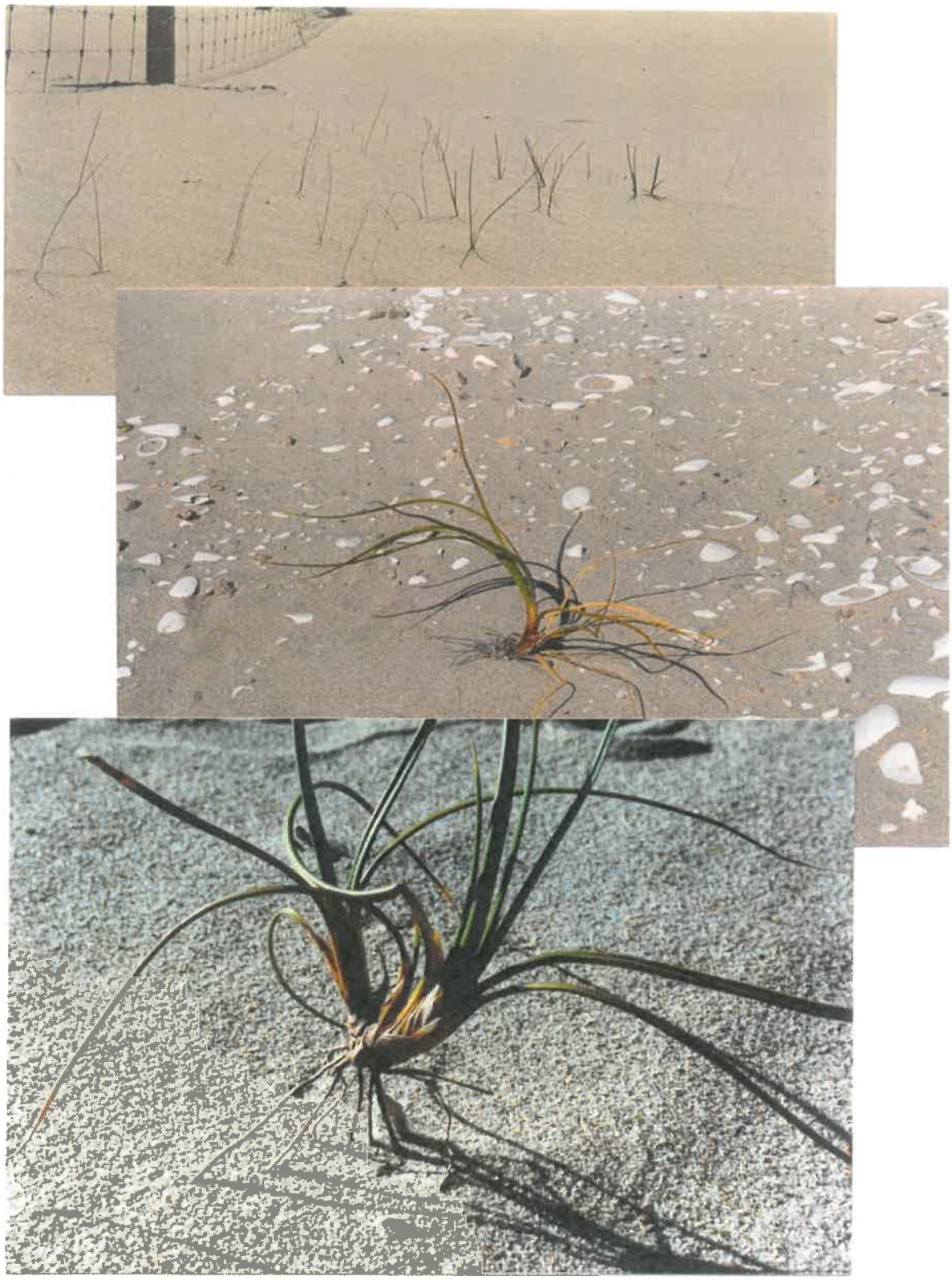

Figure 26 Pingao seedlings. Top: a "flush" of new seedlings (some already browsed by rabbits). Middle: a seedling capsized by sand being blown away from its midden site. Bottom: a seedling thriving despite sand deflation; its strong roots go deep into the sand.

Figure 27 Top: cattle damage to pingao at Plot 2, Ocean Beach, winter 1989. Much of the pingao is chewed, trampled or wrenched out. Bottom: goat browse on pingao.

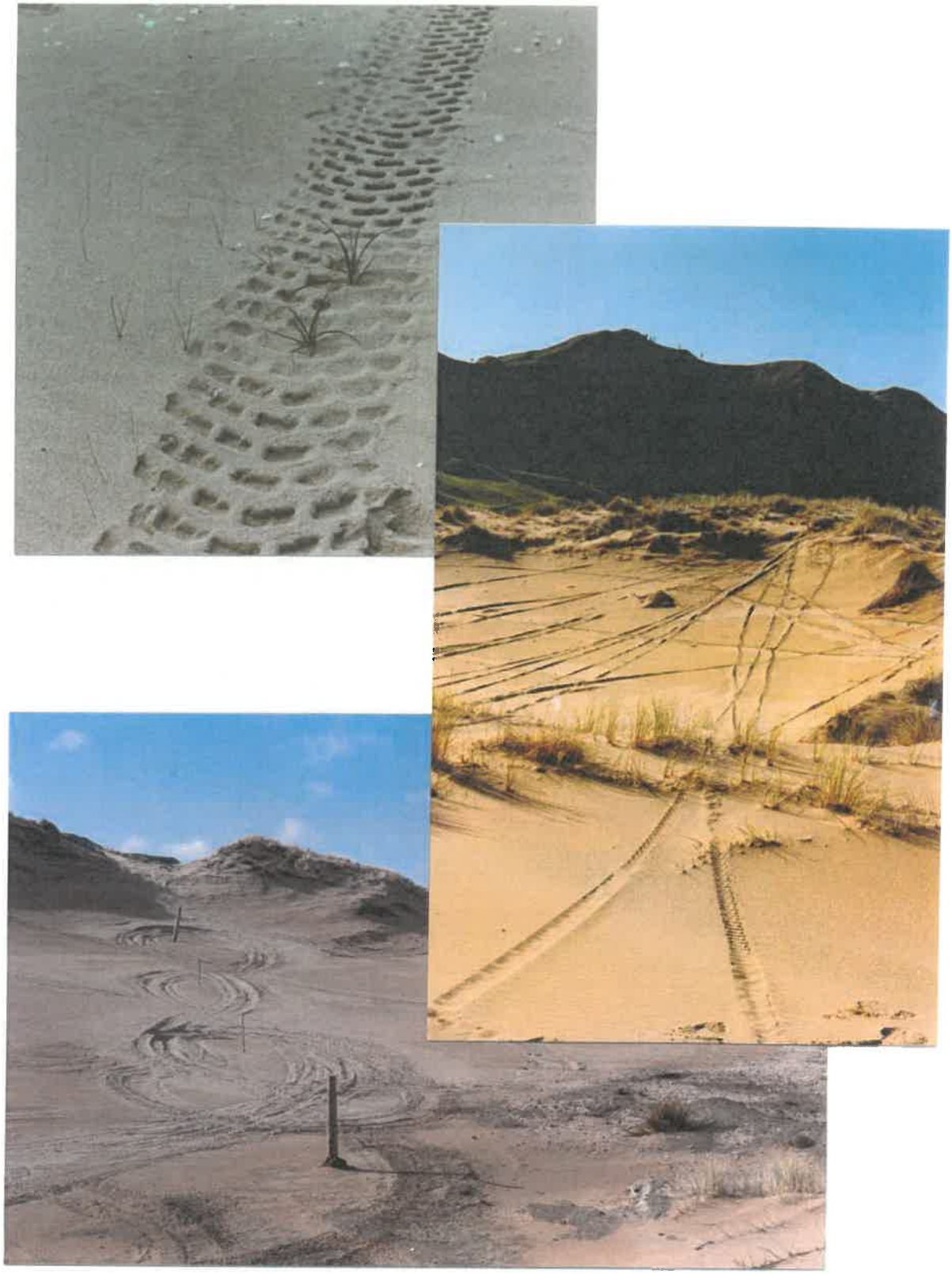

Figure 28 Vehicle impact on the Ocean Beach dunes (all photos taken at Plot 1). Top: young pingao seedlings run over and crushed.

Figure 29 The natural effect of wind on adult pingao at Ocean Beach. Top: a plant dying back on the windward (right) side but flourishing in the lee (to the left). Middle: runners exposed and killed by sand deflation from an exposed dune. Bottom: dune hulks on the skyline, held together by wind-killed pingao roots; dying pingao in the foreground.

Figure 30 Top: early stages of marram grass invasion in Plot 1, marram sharing the dunes with spinifex and pingao. Bottom: a later stage at the rabbit exclosure, with marram squeezing out the pingao.

Figure 31 Spinifex at Ocean Beach. Top: in full flower atop the small dune it has created. Middle: in healthy cohabitation with pingao. Bottom: in its element in fresh sand on the foredunes.

Figure 32 Top: young marram grass colonising mobile sand at Ocean Beach. Bottom: a large old clump of marram grass (centre of photo), having captured and stabilised a portion of the dunes.

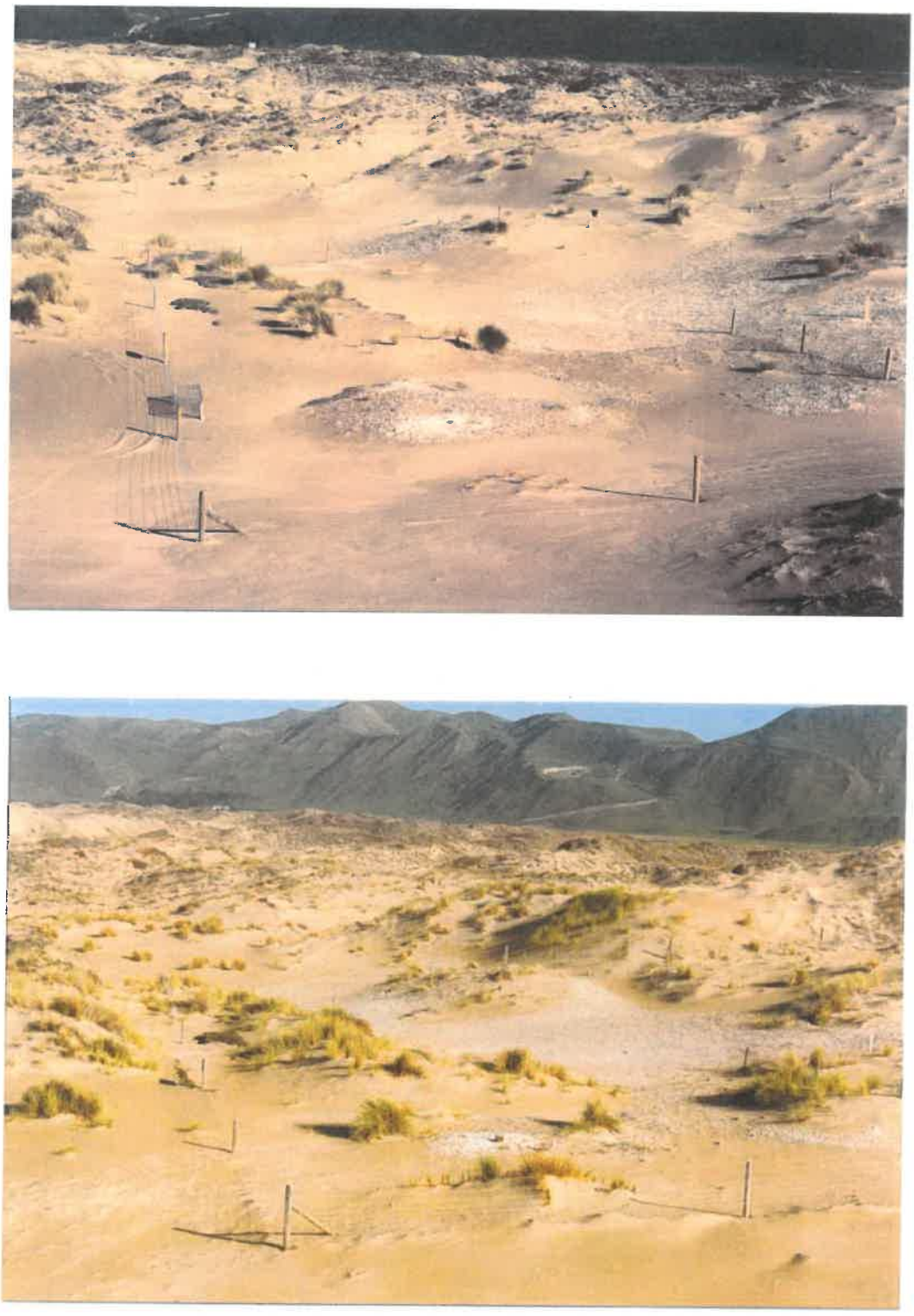

Figure 33 Views of Plot 1 showing the tremendous increase in both bulk and extent of marram grass in seven years. Top: June 1989. Bottom: June 1996.

Figure 34
Coprosma acerosa at Ocean Beach. Above: a large bush with its outliers browsed hard by rabbits. Below: the delicate tracery of young foliage in the sand.

Figure 35 Sand dynamics at Plot 1. Top: NE corner of big exclosure undermined by about 30cm of sand deflation, caused by a single storm. Bottom: raising the SW corner post of the big exclosure in June 1990, just one year after construction, because of sand build-up. By mid 1997 the sand depth had increased by over 4m in this corner.

Figure 36 Plot 2, a stable dune flat at the north end of Ocean Beach and an unusual site for pingao. Top: in July 1990, plenty of healthy adult pingao present. Bottom: in August 1997, by which time the pingao had virtually gone, choked out by competing vegetation (grasses, sedges, rushes, shore bindweed and pasture herbs).

Figure 37 Plot 3, a low foredune at the north end of Ocean Beach. Top: in July 1990. Middle: in October 1995, the pingao and spinifex having grown seawards a lot, especially to the right. Bottom: in August 1997, the sandbinders chopped back by storm-driven sea erosion.

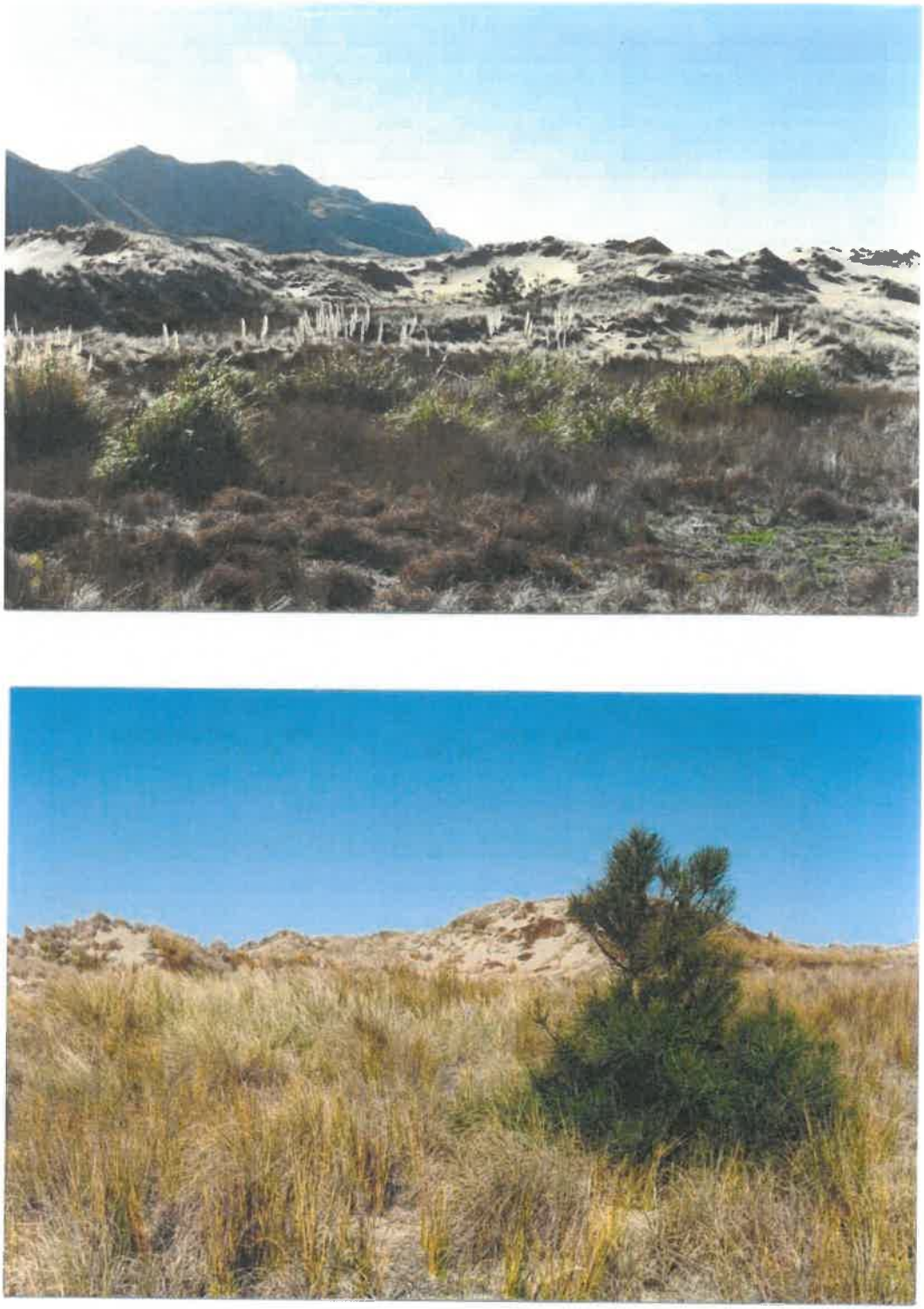

Figure 38 Two serious weeds of the Ocean Beach dunes. Top: pampas grass actively spreading in a dune hollow. Bottom: a self-sown pine, one of many appearing in the middle section of the dunes. Control done soon would nip the spread of both of these weeds in the bud before the task becomes major.