Vegetation monitoring on Moutohora (Whale Island) 1990–2002 using photopoints

DOC SCIENCE INTERNAL SERIES 126

W.B. Shaw, D.S. Gosling and L. Canham

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

DOC Science Internal Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff, or external contractors funded by DOC. It comprises progress reports and short communications that are generally peer-reviewed within DOC, but not always externally refereed. Fully refereed contract reports funded from the Conservation Services Levy (CSL) are also included.

Individual contributions to the series are first released on the departmental intranet in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are listed in the DOC Science Publishing catalogue on the departmental website http://www.doc.govt.nz and electronic copies of CSL papers can be downloaded from http://www.csl.org.nz

ISSN 1175–6519

ISBN 0–478–22453–2

In the interest of forest conservation, DOC Science Publishing supports paperless electronic publishing. When printing, recycled paper is used wherever possible.

This report was prepared for publication by DOC Science Publishing, Science & Research Unit; editing by Geoff Gregory and layout by Lynette Clelland. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

CONTENTS

Vegetation monitoring on Moutohora (Whale Island) 1990–2002 using photopoints

W.B. Shaw[1], D.S. Gosling[2] and L. Canham[3]

[1.] Wildland Consultants Ltd, PO Box 7137, Te Ngae, Rotorua
[2.] Wildland Consultants Ltd, PO Box 838, Whakatane
[3.] Department of Conservation, PO Box 1146, Rotorua

ABSTRACT

Moutohora (Whale Island) is 143 ha in size and is situated in the Bay of Plenty, 10 km offshore from Whakatane. Moutohora was acquired by the Crown in 1982 and is managed as a Wildlife Management Reserve. The vegetation on Moutohora has undergone major changes as a result of repeated human-induced fires and the effects of feral and domestic animals introduced by people. The presence of feral goats from the mid-1800s until 1977 and rabbits from 1968 to 1987 ensured that large parts of the island were kept relatively open until these species were eradicated. A network of permanent photopoints to monitor regeneration was established on Moutohora in 1990 and these have been re-photographed annually. This report provides an overview of the project, a selection of historical photographs, a time series of photographs at key photopoints, and summaries of the type and extent of vegetation change. The establishment of the network of marked photopoints in 1990, combined with analysis of an extensive collection of earlier photographs, has enabled the monitoring of a period of extensive change in the vegetation cover on Moutohora. Some of these changes have been very obvious (e.g. pohutukawa *Metrosideros excelsa* and kanuka *Kunzea ericoides* infilling of former areas of grassland), but others have been more subtle (e.g. the increasing prominence of mahoe *Melicytus ramiflorus*). The photopoint network should continue to be remeasured on an annual basis and then reviewed again in 2010.

Keywords: Moutohora Island, vegetation regeneration, vegetation surveys, photopoint surveys

1. Introduction

Wildland Consultants Ltd was commissioned by the Department of Conservation (DOC) to provide an update on vegetation monitoring on Moutohora using photopoints. A network of permanent photopoints was established by DOC on Moutohora in 1990 and these have been re-photographed annually. Two additional photopoint sites were established in 2000, to monitor vegetation change in one of the last areas dominated by bracken (*Pteridium esculentum*), club sedge (*Isolepis nodosa*), and grasses.

The photopoint network was reviewed by Shaw (1997a) who also provides summaries of vegetation observations made at each of the photopoint sites in 1990 and 1997. These records are reproduced in Appendix 1, with additional notes from observations made in 2002. Overviews of the monitoring being undertaken on Moutohora, and more widely by the Department of Conservation in the Whakatane Field Centre, are provided in Shaw (1997b; 2000). Equipment needed for photopoint remeasurement is listed in Appendix 2.

This report provides an overview of the project, a selection of historical photographs, a time series of photographs at key photopoints (Appendix 3), and summaries of the type and extent of vegetation change. Suggestions are also provided for future monitoring.

2. Background

Moutohora (Whale Island) covers c.143 ha and is situated in the Bay of Plenty, c. 10 km offshore from Whakatane. Moutohora was acquired by the Crown in 1982 and is managed as a Wildlife Management Reserve. An outline of changes in the vegetation over the period 1970–1986 is provided by Ogle (1990), and broad overviews of the management history are presented in Moore (1980), Hunt (1999), and Smale & Owen (1990). The island has a very chequered ecological and cultural history, having a long history of human occupation and use. Most of the original forest cover was burned by Maori occupants and visitors, and replaced with a mosaic of remnants of the original forest cover, secondary forest, scrub, and fernland (Fig. 1). More recent burnings have also affected the vegetation, such as the fires in 1975 and 1978 at Onepu (Sulphur Bay). The vegetation cover and pattern has been described or mapped in various publications and reports (e.g. Hall 1964; Angus & Howard 1965; and Vipond 1966—unpublished reports referred to in Parris et al. 1971). Garaway (1976) provided the following description:

Figure 1. Grassland in Hut Valley, Moutohora, 1952.

> 'Native grasses predominate on most of the clean open spaces, with here and there clumps of bracken fern (*Pteridium aquilinum*) and groves of kanuka (*Leptospermum ericoides*). Stands of ponga, or tree fern, kanuka and five-finger (*Nothopanax arboreum*) appear on the more sheltered gulleys and on the eastern promontory a dense growth of pohutukawa (*Metrosideros tomentosa*), ponga, cabbage trees (*Cordyline banksii*) and ngaios (*Myoporum laetum*). But here the pohutukawa is king, thriving on the rocky conditions offered by the island. No serious regrowth of native bush has been allowed to occur over the years due to the frequency of summer fires—encouraged by the arid conditions and by the depredations of a goat population which many years ago established itself on the island. In recent years this animal nuisance has been eradicated and already resurgence of indigenous growth is becoming evident.'

A vegetation map and type descriptions are provided by Parris et al. (1971), who mapped most of the island as grassland. A map of the vegetation pattern in the mid-1980s was also prepared by Regnier (1985) and an updated version is currently being prepared by Wildland Consultants Ltd. The geothermal site at Onepu is documented in Beadel et al. (1996). A generalised map of the vegetation pattern in 1999 is presented in Imber et al. (2000), but this is of limited use due to the broad classifications used.

During the last 100 years the island was farmed for a brief period (sheep were grazed on Moutohora from 1938–1943 (Hunt 1999)) and quarried for rock material and sulphur. There was also a very large population of feral goats (*Capra hircus*) and rabbits (*Oryctolagus cuniculus*), along with Norway rats (*Rattus norvegicus*). The goat population devastated the vegetation and, until they were controlled, ensured that there was relatively little regeneration of woody species.

Goats were present from the mid-1800s (Moore 1980) and were eradicated by the Wildlife Service in 1977. Rabbits were liberated in 1968 and eradicated (along with Norway rats) after a series of poison operations that were initiated in 1973 by the Central Bay of Plenty Pest Destruction Board. Initial poisoning in 1973 was undertaken as an aerial operation using 1080 and carrot bait and, in 1980, the island was used as the first New Zealand trial site for rabbit control using brodifacoum (Pedersen & Roche 1973; Moore 1980; D. Moore, Environment BOP, pers. comm.). In the 1980 trial the island was subdivided into eight blocks by fencing, and the following treatments were applied: brodificoum, 1080 (three blocks), and no control (two blocks) (Moore 1980). There were subsequent rabbit (and rat) control operations (mainly poisoning but trapping was also used for rabbits) in 1985 and 1987, resulting in the eradication of rabbits and Norway rats (Jansen 1993; D. Moore, Environment BOP, pers. comm.; Imber et al. 2000).

A planting programme to augment natural regeneration processes was initiated in 1984 (and continued until 1988). The indigenous species planted and their locations are set out in McGlynn (1990). Although the planting programme undoubtedly increased the diversity of species on the island (this programme was based on an assessment of species likely to have been present naturally), in retrospect it probably did little to increase or enhance the rate of natural regeneration of species that were already well established on the island, particularly pohutukawa (*Metrosideros excelsa*), kanuka (*Kunzea ericoides*), and mahoe (*Melicytus ramiflorus*). There has been subsequent planting of selected threatened species suitable for the habitats present (Shaw 1997c 1998; Gosling 1999; see also Shaw & Beadel 1997).

3. Photopoint stations and remeasurement

There are 15 separate photopoint locations, from which 33 parts of the island are photographed—refer to Table 1. Photographs have been taken annually, and there have been some changes to photopoint locations and layout at particular sites. A summary is provided in Table 1.

Beadel (1987 and 1992) provides useful background on the establishment and remeasurement of marked photopoints. The following guidelines were used for the Moutohora project:

- Once the photopoint locations had been selected, a logical route from one point to the next was established and photographs were often taken at a similar time of the day at each remeasurement.
- The photopoints were rephotographed annually (remeasurement requirements can be forgotten if visits are several years apart, especially if there are changes in personnel).
- A copy of the previous year's photographs (and a copy of the original photograph) were taken into the field each time the photopoints were rephotographed (over a period of years, the centre of a photo can 'move' significantly if a comparison with the original photo is not made at each remeasurement).
- When describing the vegetation at a site the observer(s) generally checked the view through the camera lens to compare the photograph from the previous year.
- Site marker tags were attached to steel or plastic waratahs at each site. Tags were wired top and bottom on exposed sites (some marker tags were lost when wind action eventually broke the aluminium wire holding the tags).

4. Summary of vegetation changes 1990–2002

A summary of the vegetation composition and key changes in the vegetation at each of the photopoints is presented in Table 2. A selection of historical photographs and photopoint photographs is shown in Appendix 3.

TABLE 1. A SUMMARY OF PHOTOPOINT DETAILS FOR MOUTOHORA 1990–2002.

SITE No.	LOCATION	SUBJECT	GPS COORDINATES	YEARS
1	Te Ratahi (McEwan's Bay)	Rear dune	2860498–6363960	1990–2002
2	Te Ratahi (McEwan's Bay)	East side of main hill	2860498–6363936	1990–2002
2A	Te Ratahi (McEwan's Bay)	Rear dune	2860546–6363934	2000–2002
2B	Te Ratahi (McEwan's Bay)	Rear dune	2860714–6364113	2000–2002
3	Slopes of Main Hill (east side)	Te Ratahi (McEwan's Bay) east end of island	2860230–6364010	1990–2002
3A		Looking onto cliffs	2860433–6364066	1997–2002
3B	Slopes of Main Hill (east side)	East end of island looking onto lower cliffs and beach	2860433–6364066	1990–2002
4	Onepu (Sulphur Bay) valley (west side)	West side of main hill	2859236–6364328	1990–2002
5	Onepu (Sulphur Bay) valley (west side)	West side of main hill	2859236–6364328	1990–2002
6	Onepu (Sulphur Bay) valley (west side)	West side of main hill	2859236–6364328	1990–2002
7	Oneroa (Boulder Bay) Dunes	Across foredune	(New peg 1266) 2858876–6364265	1990–2002
8	Oneroa (Boulder Bay) Dunes	Up Hut Valley	2858918–6364251	1990–2002
9A	Oneroa (adj. to Boulder Bank)	West half Raetihi (Pa Hill)	2858777–6364153	1990–2002
9B	Oneroa (adj. to Boulder Bank)	East half Raetihi (Pa Hill)	2858777–6364153	1990–2002
9C	Oneroa (adj. to Boulder Bank)	West lower slopes Raetihi (Pa Hill)	2858777–6364153	1990–2002
9D	Boulder Bank	West–middle lower slopes Raetihi (Pa Hill)	2858777–6364153	1990–2002
9E	Boulder Bank	Mid-lower slopes Raetihi (Pa Hill)	2858777–6364153	1990–2002
9F	Boulder Bank	Mid-lower slopes Raetihi (Pa Hill)	2858777–6364153	1990–2002
9G	Boulder Bank	Mid-eastern slopes Raetihi (Pa Hill)	2858777–6364153	1990–2002
9H	Boulder Bank	Eastern slopes Raetihi (Pa Hill)	2858777–6364153	1990–2002
9I	Boulder Bank	Eastern slopes Raetihi (Pa Hill)	2858777–6364153	1990–2002
10	Oneroa (Boulder Bay)	Main hill	2858777–6364153	1990–2002
10A	Oneroa (Boulder Bay)	Main hill	2858777–6364153	1990–2002
10B	Oneroa (Boulder Bay)	Main hill	2858777–6364153	1990–2002
11	Onepu (Sulphur Bay) Saddle	Onepu (Sulphur Bay) Saddle	2859370–6364555	1990–2002
12	Onepu (Sulphur Bay) Ridge	Raetihi (Pa Hill)	2859370–6364555	1990–2002
13	Hut Valley Saddle	Upper Hut Valley		1990–2002

Table 1 continued.

SITE No.	LOCATION	SUBJECT	GPS COORDINATES	YEARS
14	Raetihi (Pa Hill) Summit	Cliffs on main hill		1990–2002
15	Raetihi (Pa Hill)	East side Hut Valley	2859270–6364683	1990–1996
16	Ridge between Onepu (Sulphur Bay) and Hut Valley	Oneroa (Boulder Bay) dunes	2895220–6364346	1990–2002
17	Ridge between Onepu (Sulphur Bay) and Hut Valley	Oneroa (Boulder Bay) panorama	2895220–6364346	1997–2002
18	Ridge between Onepu (Sulphur Bay) and Hut Valley	Head of Onepu (Sulphur Bay)	2895220–6364346	1990–96, 1998–2002
18A	Ridge between Onepu (Sulphur Bay) and Hut Valley	Panorama eastern side Onepu (Sulphur Bay)	2895220–6364346	1990–2002
18B	Ridge between Onepu (Sulphur Bay) and Hut Valley	Panorama eastern side Onepu (Sulphur Bay)	2895220–6364346	1990–2002
18C	Ridge between Onepu (Sulphur Bay) and Hut Valley	Panorama eastern side Onepu (Sulphur Bay)	2895220–6364346	1990–2002
18D	Ridge between Onepu (Sulphur Bay) and Hut Valley	Panorama eastern side Onepu (Sulphur Bay)	2895220–6364346	1997–2002
18E	Ridge between Onepu (Sulphur Bay) and Hut Valley	Panorama eastern side Onepu (Sulphur Bay)	2895220–6364346	1997
19	Ridge between Onepu (Sulphur Bay) and Hut Valley	Ridge crest	2895220–6364346	1990–2002
HH1	Mid-slopes Raetihi (Pa Hill)	Lower slopes of Raetihi (Pa Hill)	2858882–6364709	1990–2002
HH2	Mid-slopes Raetihi (Pa Hill)	Lower slopes of Raetihi (Pa Hill)	2858882–6364709	1990–2002
HH2	Mid-slopes Raetihi (Pa Hill)	Lower slopes of Raetihi (Pa Hill)	2858882–6364709	1990–95, 1997–2002

5. Discussion and conclusions

The vegetation on Moutohora has undergone major changes as a result of repeated human-induced fires and the effects of feral and domestic animals introduced by people. The presence of feral goats from the mid-1800s until 1977 and rabbits from 1968 to 1987 ensured that large parts of the island were kept relatively open until these species were eradicated.

The initial patterns of vegetation recovery following reduction of and removal of goats and rabbits are complex due to the population reductions and subsequent eradications being achieved in stages. This means that initial vegetation changes are not easily interpreted based solely on photographs taken prior to 1990, and it is also necessary to consider the observations of previous workers and records of key events. By the late 1950s there was a very large goat population, which had devastated the vegetation. Goat control was initiated by the Department of Internal Affairs in 1958 (Hunt 1999) and a major reduction of

TABLE 2. SUMMARY OF VEGETATION CHANGES ON MOUTOHORA 1990–2002 AT EACH OF THE PHOTOPOINT LOCATIONS.

SITE No.	PREVIOUS VEGETATION	VEGETATION 2002	KEY CHANGES
1	1990. Local pohutukawa and ngaio; relatively open vegetation on dune.	Pohutukawa, ngaio, cabbage tree seedlings; dense cover on dune.	No bare ground remains.
2	1990. Patches of pohutukawa, kanuka, bracken, open areas.	Mainly pohutukawa forest with some patches of kanuka and ngaio.	Virtually closed forest cover over area that was formerly mosaic.
2A	2000. Scattered pohutukawa and other tree species. Dead bracken.	Trees similar to 2000, but taller. Thick groundcover of Yorkshire fog and other species.	Trees taller. More cabbage trees present.
2B	2000. Scattered pohutukawa and other tree species over bracken and fleabane. Dead bracken.	Similar to 2000.	Similar to 2000.
3	1990. Pohutukawa forest covers much of eastern end of island; mahoe forest at base of scarp; bracken on isthmus, with scattered pohutukawa and ngaio.	Mainly denser pohutukawa forest, limited open areas on end of island and area of bracken has diminished on isthmus, mahoe still evident at base of scarp.	Loss of open areas of bracken fernland. This area has undergone huge change since c.1970.
3A	1997. Pohutukawa seedlings and saplings, windshorn kanuka; pohutukawa forest.	Similar to 1997 but pohutukawa larger and cover more area	Little change evident, but pohutukawa larger.
3B	Pohutukawa forest on steep cliff.	Similar to 1997.	Little change evident.
4	1990. Kanuka shrubland, some pohutukawa in valley floor; one large remnant pohutukawa.	Similar to 1990.	Little change evident.
5	1990. Large remnant pohutukawa; kanuka shrubland, some kanuka dying; mahoe appearing in canopy.	Similar to 1990.	Little change evident.
6	1990. Kanuka scrub on lower slopes; midslope kanuka-mahoe forest; upper-slopes pohutukawa/kanuka forest.	Similar to 1990 but areas of grassland showing in 1990 replaced by pohutukawa and mahoe.	Grassland replaced by pohutukawa and mahoe, and subcanopy developing.
7	1990. Spinifex and scattered tauhinu.	Spinifex and scattered tauhinu.	Little change since 1990.
8	1990. Kanuka scrub and scattered pohutukawa. Grassland at head of Hut Valley.	Kanuka scrub and forest, pohutukawa forest. Very small area of grassland at head of Hut Valley.	Kanuka much taller, more pohutukawa.
9A	1990. Panorama. Spinifex on dunes. Low kanuka and extensive areas of grassland on hillslopes with occasional pohutukawa emergent.	Seasonal erosion of duneland showing with spinifex similar to 1990 hillslopes dominated by kanuka and pohutukawa forest.	Grassland replaced by pohutukawa and kanuka forest.
9B	1990. Panorama. Pohutukawa forest on hill crest and on lower face. Area of windshorn kanuka and grassland.	Pohutukawa forest covers much of the site with kanuka shrubland in places on hillslopes.	Grassland replaced by pohutukawa and kanuka.
9C	1990. Panorama. Spinifex on duneland with scattered pohutukawa emergent over windshorn kanuka scrub and pohutukawa saplings and grassland.	Spinifex on duneland with pohutukawa forest on hillslope. Kanuka locally common.	Pohutukawa forest now dominates the site.
9D	1990. Panorama. Spinifex on sand dunes with area of pohutukawa at base of hillslope. Hillslope predominantly grassland and kanuka scrub with emergent pohutukawa saplings and trees throughout.	Spinifex on sand dunes with pohutukawa forest on hillslopes with kanuka shrubland dominant at the eastern end of the site.	Pohutukawa forest now covers most of the site. Grassland no longer present.

Table 2 continued.

SITE No.	PREVIOUS VEGETATION	VEGETATION 2002	KEY CHANGES
9E	1990. Panorama. Spinifex on dunes with area of pampas at the base of the hillslope. Pohutukawa and kanuka dominant lower slopes.	Pohutukawa forest on lower hillslopes and western part of site and eastern gully, and kanuka shrubland over much of the midslopes.	Grassland replaced by kanuka and pohutukawa. No pampas present.
9F	1990. Panorama. Pohutukawa forest in gully and upper hillslopes. Kanuka scrub and grassland with occasional emergent pohutukawa on lower slopes.	Pohutukawa forest in gully and upper hillslopes. Kanuka shrubland with occasional emergent pohutukawa on lower slopes.	Grassland replaced by kanuka and pohutukawa.
9G	1990. Panorama. Scattered pohutukawa emergent over kanuka scrub with areas of grassland in places.	Kanuka shrubland with scattered emergent pohutukawa.	Grassland no longer evident.
9H	1990. Panorama. Pohutukawa forest in gully and upper hillslopes with kanuka on midslope and grassland at eastern end of site.	Pohutukawa forest in gully and kanuka shrubland on hillslopes with pohutukawa commonly emergent.	Grassland almost completely infilled with pohutukawa and kanuka.
10 & 10A	1990. Panorama. Areas of pohutukawa forest on lower slopes with windshorn kanuka on the ridge between Oneroa (Boulder Bay) and Onepu. Kanuka-mahoe shrubland on western face of Motu Hara (Main Summit) with occasional emergent pohutukawa. An area of grassland with frequent emergent pohutukawa on the summit, extending down the south-eastern side.	Pohutukawa forest dominates the lower slopes and cliff edges with kanuka-mahoe shrubland covering the western face of the main dome and summit. Some emergent pohutukawa over windshorn kanuka on the ridge between Oneroa and Onepu.	Grassland no longer evident—replaced by kanuka, mahoe and pohutukawa. Mahoe very prominent across large section of mid-upper slopes. New hut visible at Oneroa.
11	1990. Thick low cover of kanuka scrub, occasional pohutukawa; open area on saddle.	Kanuka scrub, taller than 1990; scattered emergent pohutukawa; no open area.	Kanuka taller, more pohutukawa, no open area.
12	1990. Background—pohutukawa forest, some unhealthy trees; mamaku in gullies; foreground—kanuka shrubland and grassland with regenerating pohutukawa.	Background—similar to 1990, trees relatively healthy; foreground—pohutukawa scrub and kanuka, limited areas of grassland.	Infilling of grassland with kanuka and pohutukawa.
13	1990. Mainly grassland, with scattered pohutukawa seedlings and saplings.	Pohutukawa-dominant, 3–6 m tall, limited areas of kanuka and grassland.	Major infilling of grassland with pohutukawa scrub and forest.
14	1990. Scattered pohutukawa on cliffs, denser near top of hill; also areas of kanuka shrubland and grassland.	Pohutukawa forest on cliffs. Kanuka-mahoe forest on main face below summit. Abundant kanuka on lower face.	Infilling of grassland, increased height of vegetation, increased cover of kanuka, pohutukawa, and mahoe.
15	1990. Mainly grassland with scattered regeneration of pohutukawa; band of kanuka scrub on side ridge.	Limited area of grassland with scattered pohutukawa trees, bands of pohutukawa forest and kanuka scrub.	Dramatic infilling of grassland, markedly increased area of pohutukawa forest, much larger area of kanuka.
16	1990. Mainly kanuka scrub.	Mainly kanuka scrub.	Kanuka scrub taller.
17	1990. Kanuka scrub and pohutukawa.	Similar to 1990.	Limited change since 1990.
18A	1990. Kanuka scrub.	Kanuka-dominant scrub, one emergent rewarewa.	Kanuka scrub taller.
18B	1990. Kanuka scrub.	Kanuka-dominant scrub, some kanuka dead.	Kanuka taller, some dieback.

Table 2 continued.

SITE No.	PREVIOUS VEGETATION	VEGETATION 2002	KEY CHANGES
18C	1990. Kanuka scrub.	Kanuka-dominant forest with scattered emergent pohutukawa.	Presence of emergent pohutukawa.
18D	1990. Kanuka scrub.	Mahoe-dominant forest with kanuka common.	Dominance of mahoe, major loss of kanuka.
18E	1990. Kanuka scrub, local pohutukawa.	Patches of mahoe forest and kanuka forest, with scattered emergent pohutukawa.	Local dominance of mahoe.
19	1990. Kanuka scrub.	Kanuka-dominant scrub with occasional pohutukawa, patches of kanuka-mingimingi scrub.	Little change evident.
HH1	1997. Bare sand on beach, with spinifex and *Cassinia leptophylla* in places. Kanuka scrub and grassland, with frequent emergent pohutukawa on hillslopes.	Bare sand on beach. Pohutukawa shrubland obscures view of site.	Pohutukawa shrubland dominant.
HH2	1997. Grassland with frequent wind-shorn kanuka and pohutukawa covers much of the site.	Hand held photopoint 2 had to be moved westward as pohutukawa trees obscured original view.	Pohutukawa forest and shrubland dominates the site with kanuka shrubland present in places. Small areas of club sedge and bare ground present throughout.

goat numbers in 1964 enabled rapid local regeneration of kanuka and pohutukawa in some open areas and recovery of mahoe in the understorey of pohutukawa forest (Ogle 1990). Figure 2 illustrates the rapid improvement of pohutukawa forest understorey between 1964 and 1966.

The reduction of goat numbers also enabled the development of grassland on previous areas of bare soil. Goats had been at low numbers since the early 1960s and eradication was achieved in 1977. Vegetation recovery suffered a major setback in 1968, when rabbits were liberated illegally, and numbers rose rapidly to levels of c. 350/ha in 1973 (Moore 1980). Rabbits had major impacts on regenerating forest and grassland, and control operations were started in 1973 (Moore 1980). Two further rabbit poisoning operations were undertaken and

1964

1966

Figure 2. Recovery of pohutukawa forest understorey in the mid-1960s, Moutohora.

eradication was achieved in 1987, along with Norway rats (Hunt 1999). The effects on plants of removing Norway rats is not known, but they would have consumed significant quantities of plant seeds.

The reduction of goat numbers in the late 1950s to early 1960s promoted a regeneration pulse of pohutukawa and kanuka on open sites, and mahoe in forest understoreys. Ogle (1990), discussing the area east of Ratahi (McEwan's Bay) considered that pohutukawa 3–4 m high established after the major reduction of goat numbers in 1964, although he also notes that there was some planting of pohutukawa and cabbage tree in this area in the mid-1970s. Ogle (1990) also notes that 1-m-high pohutukawa east of Ratahi (McEwan's Bay) probably appeared after the rabbit poisoning operation in 1973. Irrespective of the exact sequence, it is apparent that much of the eastern end of Moutohora changed from grassland to dense pohutukawa forest over the 15-year period from 1970–1985 (cf. figs 6 and 7 in Ogle 1990). This trend has continued. Areas that were open grassland in the late 1980s are now also covered with pohutukawa forest (refer to Fig. 6, Appendix 3).

Until they were eradicated, rabbits continued to maintain large areas of low turf cover where scattered club sedge was the only species of any prominence, but it is evident that rabbit control operations prior to eradication in 1987 also allowed pulses of regeneration of woody species, although this was not universal. A major reduction of rabbits in 1980 promoted local regeneration of woody species (D. Moore, Environment BOP, pers. comm.). The lower section of Hut Valley was a low turf in 1980 but by 1985 there was a dense low sward of kanuka shrubs (see Appendix 3, Fig. 3). This is in marked contrast to the head of Hut Valley and the isthmus adjacent to Te Ratahi (McEwan's Bay) where low turf was still present in the mid-1980s—this was replaced with rank grassland dominated by *Microlaena stipoides* by 1990. Pohutukawa subsequently established rapidly in the grassland, to form pohutukawa forest or treeland by 2002 (see Figs 11 & 15, Appendix 3). A similar sequence is evident on the lower slopes on the eastern side of Motu Hara (Main Summit) and on the lower slopes of Raetihi (Pa Hill). The latter site was still mainly grassland in 1990 (although there had been planting of a range of indigenous species), but many thousands of pohutukawa seedlings established naturally over the next decade, to cover this area in pohutukawa-dominant forest and treeland.

It is evident that the extraordinarily rapid rate of natural regeneration of pohutukawa, kanuka, and mahoe was well underway prior to the planting programme initiated in the mid-1980s, though the planting has improved seasonal food supplies and habitat diversity for indigenous avifauna.

Pohutukawa and kanuka have continued to establish at an extraordinary rate and in high densities in areas of grassland in various pulses since c. 1964, including the period 1990–2002. Examples include the eastern side of Motu Hara (main summit—see Fig. 5, Appendix 3), the isthmus behind Te Ratahi (McEwan's Bay—see Fig. 6, Appendix 3), the lower slopes of Raetihi (Pa Hill—see Figs 8 & 13, Appendix 3), and the upper southern slopes of Motu Hara (main summit—see Fig. 9, Appendix 3).

Mahoe has become increasingly prominent on the mid- to upper-slopes of Motu Hara (Main Summit) at the expense of kanuka and there has been ongoing self-thinning and dieback of kanuka. (See Figs 9 & 13, Appendix 3). The upper

slopes changed from grassland to pohutukawa/kanuka-mahoe scrub over the period 1990–1996 and there has since been ongoing loss of kanuka and increasing dominance of mahoe in the canopy. A significant increase in mahoe occurred over the period 1996–2002, and change was also evident over the 12-month-period 2001–02. The establishment of mahoe in this area has undoubtedly originated from the patch of mature mahoe forest on the summit (Motu Hara) which survived many fires and the effects of prolonged animal browsing.

The dense kanuka scrub which established at Onepu (Sulphur Bay Valley) following fires in the 1970s is similar to the regeneration sequence evident on other parts of the island following heavy goat and rabbit damage.

The establishment of the network of marked photopoints in 1990, combined with analysis of an extensive collection of earlier photographs, has enabled the monitoring of a period of extensive change in the vegetation cover on Moutohora[1]. Some of these changes have been very obvious (e.g. pohutukawa and kanuka infilling of former areas of grassland), but others have been more subtle (e.g. the increasing prominence of mahoe). The photopoint network should continue to be remeasured on an annual basis and then reviewed again in eight years (2010).

Moutohora continues to provide an impressive example of the scale and rate of natural regeneration possible when damaging animal pests are removed and large seed sources are available. It also provides a useful comparison with mainland situations, though it must be noted that the absence of exotic grasses such as kikuyu (*Pennisetum clandestinum*) on Moutohora means that the grassland regeneration sequences on the island are different from most mainland sites.

6. Acknowledgements

This project was undertaken for the Department of conservation, under the Unprogrammed Science Advice fund and Joanne Deeley provided initial project liaison. All photographs reproduced here are held by the Department of Conservation, Rotorua (pre-1987 photographs were taken by staff of the New Zealand Wildlife Service). Historical photographs and other useful information were provided by the Whakatane Museum and the Department of Conservation. Useful assistance and comments were provided by the following Department of Conservation staff: Dave Harding, Nancy Willems, Matt Cook, Paul Cashmore, and Brendon Christensen. Information on pest control operations was provided by David Moore (Environment BOP).

1. Other techniques are also being used to monitor vegetation change: re-mapping of the vegetation pattern in 2002 and permanent vegetation monitoring plots.

7. References

Beadel, S.M. 1987: Assessment of vegetation condition using permanent photographic points, Horomanga Catchment, Urewera National Park. Regional Report Series No. 2, Department of Conservation, Rotorua. 48 p.

Beadel, S.M. 1992: Indigenous forest monitoring using photopoints. Unpublished Wildland Consultants Ltd Contract Report prepared for Science & Research Unit, Department of Conservation, Wellington. 21 p.

Beadel, S.M.; MacKinnon, S.; Shaw, W.B. 1996: Geothermal vegetation of the Bay of Plenty Region. Unpublished Wildland Consultants Ltd Contract Report No. 155. Prepared for Environment Bay of Plenty. 234 p.

Garaway, A.H. 1976: Motuhora, or Whale Island: an outline history. *Historical Review 24*(*1*): 1–7.

Gosling, D.S. 1999: Moutohora[2] threatened plants transfer proposal. Unpublished Wildland Consultants Ltd Contract Report No. 262. Prepared for Department of Conservation, Whakatane. 9 p.

Hunt, D.S. 1999: Moutohora (Whale) Island Conservation Management Plan. Department of Conservation, Rotorua.

Imber, M.; Harrison, M.; Harrison, J. 2000: Interactions between petrels, rats and rabbits on Whale Island, and effects of rat and rabbit eradication. *New Zealand Journal of Ecology 24*(*2*): 153–160.

Jansen, W.P. 1993: Eradication of Norway rats and rabbits from Moutohora (Whale) Island, Bay of Plenty. Unpublished report. Department of Conservation, Rotorua.

McGlynn, M. 1990: Motuhora[2] (Whale Island) planting programme 1984–1989. *New Zealand Botanical Society Newsletter 21*: 7–12.

Moore, D.S. 1980: Whale Island brodifacoum trial 21st April to 9th December 1980. Unpublished file report, Central Bay of Plenty Pest Destruction Board.

Ogle, C.C. 1990: Changes in the vegetation and vascular flora of Motuhora (Whale Island) 1970–1986. *Tane 32*: 19–48.

Parris, B.S.; Lynch, P.A.; Ferguson, E.J. 1971: The vegetation of Whale Island Part 1: the plant communities. *Tane 17*: 33–38.

Pedersen, E.D.; Roche, E.B. 1973: End of a rabbit infestation. *New Zealand Journal of Agriculture 158*: 45–47.

Regnier, C. 1985: Vegetation type map and description of Motuhora Wildlife Refuge. Unpublished report. Copy held by Department of Conservation, Rotorua.

Shaw, W.B. 1997a: Moutohora photopoints—remeasurement and review. Unpublished Wildland Consultants Ltd Contract Report No. 182. Prepared for Department of Conservation, Whakatane. 38 p.

Shaw, W.B. 1997b: Vegetation survey and monitoring in Whakatane Field Centre. Unpublished Wildland Consultants Ltd Contract Report No. 188. Prepared for the Department of Conservation. 129 p.

Shaw, W.B. 1997c: Ecosystem-based restoration of Moutohora: threatened plants. Unpublished Wildland Consultants Ltd Contract Report No. 184. Prepared for Department of Conservation. 9 p.

Shaw, W.B. 1998: Ecosystem-based restoration of Moutohora: threatened plants. *Conservation Advisory Science Notes: 211*, Department of Conservation, Wellington. 6 p.

---

2. Moutohora is the currently accepted spelling.

Shaw, W.B. 2000: Vegetation survey and monitoring in Whakatane Field Centre. *Conservation Advisory Science Notes: 273*, Department of Conservation, Wellington. 22 p.

Shaw, W.B.; Beadel, S.M. 1997: Vascular plant taxa of conservation concern in Whakatane Field Centre—a review. Unpublished Wildland Consultants Ltd Contract Report No. 186. Prepared for Department of Conservation. 24 p.

Smale, S.; Owen, K. 1990: Moutohora; a whale of an island. *In*: Towns, D.R.; Daugherty, C.H.; Atkinson, I.A.E. (Eds): Ecological Restoration of New Zealand Islands. *Conservation Sciences Publication No. 2*, Department of Conservation, Wellington. 320 p.

Appendix 1

NOTES FROM PHOTOPOINT MEASUREMENTS—1990, 1997, 2002

#1 TE RATAHI (McEWAN'S BAY) (1990)

Date Established: 28 March 1990, 11.00 a.m.

Camera: Minolta 35–135 mm lens, set at 35 mm

Location: 20 m from back of beach, on western side of bay

Photo Subject: Sandy area behind bay

Photo Information: Tripod height (to base of camera): 1430 mm

Camera angle:

Vegetation: Background—pohutukawa and ngaio

Mid ground—pohutukawa, ngaio, club sedge (*Isolepis nodosa*), fleabane (*Conyza albida*), lupin (*Lupinus arboreus*) (rare), harestail (*Lagurus ovatus*), dead lupin (*Lupinus arboreus*), *Conyza bonariensis, Cyperus ustulatus,* bare sand.

#1 TE RATAHI (McEWAN'S BAY) (1997)

Date: 1 April 1997

Comments: Retain photopoint; some minor pruning needed of pohutukawa overhanging camera site. Photo needs to be taken later in day, due to sun angle.

Vegetation: Scattered pohutukawa c. 8-m-tall over club sedge-fleabane-(tree lucerne). Former ngaio (*Myoporum laetum*) in photo centre now dead; two pohutukawa on the site formerly occupied by *Myoporum laetum*. Other species present: *Lagurus ovatus* (common), catsear (abundant), *Calystegia soldanella* (abundant), Australian fireweed (occasional), paspalum (occasional).

Cover varies markedly; some areas of bare sand, and patches with a thick cover of club sedge (*Isolepis nodosa*)/*Calystegia soldanella*-catsear. Pohutukawa continuing to establish on the site; seedlings 0.3–1 m in height.

#1 TE RATAHI (McEWAN'S BAY) (2002)

Date: 8 January 2002

Vegetation: Complete vegetated cover with virtually no bare ground remaining. Scattered pohutukawa trees to 8 m with scattered seedlings to 1–2 m. A few cabbage trees to c. 1 m; abundant club sedge (*Isolepis nodosa*) locally abundant *Calystegia sepium*, with Yorkshire fog, harestail (*Lagurus ovatus*), *Trifolium dubium, Asplenium oblongifolium*, and local *Paspalam dilatatum*. Occasional *Lupinus arboreus*, *Coprosma robusta*, *Lilium formosanum*, fleabane, and abundant 'hawkbit'.

Foredune adjacent to #1 is covered with locally abundant spinifex (*Spinifex sericeus*), with scattered fleabane and lupin.

#2 TE RATAHI (McEWAN'S BAY) (1990)

Date Established: 8 March 1990, 11.15 a.m.

Camera: Minolta 35–135 mm lens set on 35 mm
Film—Fuji 200 colour print

Location: Eastern side of sandy area at back of Te Ratahi (McEwan's Bay)

Photo Subject: Eastern side of main hill

Photo Information: Tripod height: 1430 mm
Camera angle: 10° tilt
Location marked with waratah standard

Vegetation: Pohutukawa-kanuka-bracken-club sedge
'Grassland' areas appear to be predominantly club sedge

Pohutukawa regeneration common amongst the club sedge; also abundant fleabane, *Pteris tremula, Holcus lanatus.*

#2 TE RATAHI (McEWAN'S BAY) (1997)

Date: 1 April 1997

Comments: Minor pruning of pohutukawa required above stake. Good photopoint—should be maintained.

Vegetation:

Foreground
Similar to #1. Bare ground; vegetated areas covered with tree lucerne/club sedge/catsear-(sheep's sorrel)-white clover-Yorkshire fog. Fleabane scattered throughout. Significant areas of sand now covered with vegetation.

Background
Mainly pohutukawa with kanuka filling the gaps (previously grass and bracken) between pohutukawa. Still a strip of grassland up the ridge line. Also cabbage tree, ngaio, mamaku.

#2 TE RATAHI (McEWAN'S BAY) (2002)

Date: 8 January 2002

Vegetation:

Foreground
Small area of open sand but otherwise a thick cover of club sedge with scattered lupin and fleabane; abundant Yorkshire fog, harestail, local paspalum and *Lilium formosanum.* Occasional *Coprosma robusta*, abundant catsear.

Background
Mainly pohutukawa with some patches of kanuka and ngaio.
Much of the vegetation cover is now pohutukawa forest, with some minor variation. Patch of kanuka present, with pohutukawa evident amongst kanuka. Mahoe present near top of the slope. Minor patches of grass on leading ridge to summit. Occasional cabbage tree.

#2A TE RATAHI (MCEWAN'S BAY) (2000)

Date Established: 6 March 2000

Location: Site is 30–40 m north of #2

Subject: Saddle behind Te Ratahi (McEwan's Bay)

Comments: Marked with white plastic standard, tag #4252

Vegetation: Pohutukawa to 6 m on fringe and single cabbage tree and low-growing ngaio, hangehange, and mahoe. The groundcover is mainly bracken, club sedge, Yorkshire fog, and *Poa anceps* subsp. *anceps*, with occasional *Asplenium oblongifolium*, *Lilium formosanum*, and fleabane to c. 0.5 m.

Much of the bracken is dead but some new regrowth is evident

#2A TE RATAHI (McEWAN'S BAY) (2002)

Date: 8 January 2002

Vegetation: Scattered pohutukawa 4–8 m high, with occasional ngaio to 2 m. Thick groundcover of club sedge with Yorkshire fog, scattered bracken (some dead) and *Asplenium oblongifolium*, local plume grass, a few bushes of kanuka, hangehange and mahoe. Three cabbage trees to c. 1 m.

#2B TE RATAHI (McEWAN'S BAY) (2000)

Date Established: 6 March 2000

Location: Site is c. 30 m NE of #2A, c. 8 m from edge of northern cliff

Subject: Saddle behind Te Ratahi (McEwan's Bay)

Comments: White plastic standard (no tag) at base of hangehange

Vegetation: Scattered pohutukawa, ngaio, mahoe, cabbage tree and hangehange to 6 m over bracken and fleabane to 1 m tall. Much of the bracken is dead, but regrowth is common. Single kanuka adjacent to cabbage tree in centre of frame. Occasional *Lilium formosanum* and club sedge.

MOUTOHORA #2B McEWAN'S (2002)

Date: 8 January 2002

Vegetation: Scattered pohutukawa to c. 8 m with some 1–3 m tall. Several cabbage trees 1–4 m tall. Site is covered mainly with bracken (some dead), with patches of Yorkshire fog, scattered club sedge, local *Senecio bipinnatisectus*, catsear, and fleabane. Local hangehange, kanuka (to 2 m), *Coprosma robusta*.

#3 TE RATAHI (McEWAN'S BAY) (1990)

Date Established: 28 March 1990, 12.30 p.m.

Camera: Minolta 35–135 mm lens, set at 35 mm

Location: On slopes of main hill (eastern side)

Photo Subject: Te Ratahi (McEwan's Bay) and east end of island

Photo Information: Tripod height: 1320 mm
Camera angle: 8°
Location marked with waratah standard

Vegetation: Predominantly pohutukawa forest, also significant areas of bracken fernland; club sedge sedgeland, low pohutukawa forest on sand; ngaio forest (on slopes), sand. Quite large numbers of cabbage tree amongst pohutukawa forest.

Notes: Between two large pohutukawa trees on cliff edge. Site diagonally above 'rat gnaw stick 40' (210°).

Took hand-held shot 35 mm lens of cliffs from adjacent to 'rat gnaw stick 37'. Pohutukawa forest and regeneration on steep grassy slopes; some low kanuka.

#3 TE RATAHI (McEWAN'S BAY) (2002)

Date: 8 January 2002

Vegetation: Vegetation composition appears very similar to 1990 description, although pohutukawa behind Te Ratahi (McEwan's Bay) are larger and cover more of former open area.

#3A TE RATAHI (McEWAN'S BAY) (1997)

Date Established: 1 April 1997

Location: On eastern side of main hill, above Te Ratahi

Subject: Hand-held site, on ridge looking onto back face of island

Vegetation: **Foreground**
Pohutukawa seedlings and saplings; also lupin, ratstail, club sedge
Kanuka (windshorn) locally dominant

Rear
Pohutukawa forest on cliffs

Notes:
1. 17 mm lens used for this site
2. Need to establish marker peg on site
3. Photo taken midway between two large pohutukawa on ridgeline

#3A TE RATAHI (McEWAN'S BAY) (2002)

Date: 8 January 2002

Vegetation: Similar to 1997 description. Background—pohutukawa 'forest' on cliffs more of a treeland, especially on the back ridge.

#3B TE RATAHI (McEWAN'S BAY) (1997)

Date Established: 1 April 1997

Location: On slopes of main hill (eastern side)

Subject: Entire east end of island—all pohutukawa forest

Comments: Site needs to be marked with steel peg

Vegetation: Pohutukawa forest
Mahoe forest at base of scarp
Still a reasonable sized area of bracken-(club sedge) on isthmus, with scattered pohutukawa and ngaio.

#3B TE RATAHI (McEWAN'S BAY) (2002)

Date: 8 January 2002

Vegetation: Similar to 1997 description

#4 ONEPU (SULPHUR BAY VALLEY) (1990)

Date Established: 28 March 1990, 2.15 p.m.

Camera: 34 mm lens

Location: Western side of Onepu (Sulphur Bay) valley; c. 150 m from beach; on valley side. Jumble of rocks where standard located.

Photo Subject: Secondary kanuka that has established following fire, including the head of the Onepu (Sulphur Bay) valley.

Photo Information: Camera angle: straight

Vegetation: Kanuka shrubland, some pohutukawa in valley floor; one large remnant pohutukawa near head of valley.

#4 ONEPU (SULPHUR BAY VALLEY) (1997)

Date: 2 April 1997

Vegetation: 1. Head of valley described in 18a

2. Valley floor = low kanuka and mingimingi c. 1 m high. Dead stems common in scrub; 70% kanuka, 10–15% mingimingi; remainder open.

#4A ONEPU (SULPHUR BAY VALLEY) (2002)

Date: 8 January 2002

Vegetation: Very similar to 1997. Top of valley—kanuka scrub is the main vegetation cover, with a few pohutukawa near valley floor and on left hand side of valley. In the valley floor there are some open areas of geothermal sinter with patches of scrub dominated by kanuka and mingimingi (*Leucopogon fasciculatus*).

#4B ONEPU (SULPHUR BAY VALLEY) (2002)

Date: 8 January 2002

Vegetation: Large remnant pohutukawa high on slope, with a thick kanuka-dominant canopy. Also a strip of mahoe forest high on slope, interspersed with occasional kanuka. Scattered dead kanuka throughout.

#4C ONEPU (SULPHUR BAY VALLEY) (2002)

Date: 8 January 2002

Vegetation: Essentially unchanged since 2001. Kanuka-dominant secondary forest with mahoe scattered throughout and low numbers of pohutukawa. Occasional cabbage tree. Pohutukawa more common in background. Remnant unhealthy pohutukawa in foreground appear to have more foliage than 1997 (or 2001?). Dead kanuka scattered throughout.

#5 ONEPU (SULPHUR BAY) VALLEY (1990)

Date Established: 28 March 1990, 12.20 p.m.

Camera: 35 mm lens

Photo Subject: Eastern side of Onepu (Sulphur Bay) valley

Photo Information: Tripod height (to base of camera): 1430 mm
Camera angle: 15°

Vegetation: #5—large remnant pohutukawa and kanuka shrubland. Some kanuka starting to die; mahoe starting to appear in canopy.
#6—Panorama to right of #5. Similar to #5 but pohutukawa = abundant epicormic shoots on right-hand side of photo.

Notes: Waratah behind large rock

#5 ONEPU (SULPHUR BAY) VALLEY (1997)

Date: 2 April 1997

Vegetation: Lower—slopes kanuka scrub
Upper—scattered pohutukawa trees/kanuka-mahoe

#5 ONEPU (SULPHUR BAY) VALLEY (2002)

Date: 8 January 2002

Vegetation: Similar to 1997

#6 MOUTOHORA (1997)

Date Established: 2 April 1997

Vegetation: Lower—slopes kanuka scrub
Midslope—kanuka-mahoe
Upper—pohutukawa regeneration/kanuka

#7 ONEROA (BOULDER BAY) (1990)

Date Established: 28 March 1990, 3.40 p.m.

Camera: 35 mm lens

Location: Photopoint at top of dune to west of track. Photo to south towards Putauaki/ Boulder Bank, across foredune.

Photo Subject: Dune system/*Spinifex* encroachment

Photo Information: Tripod height (to base of camera): 1370 mm
Camera angle: flat

Vegetation: *Spinifex* and a few scattered tauhinu bushes. Also fleabane and pingao (rare).

Notes: White waratah, located to west of another white waratah (photopoint #8), looking up Hut Valley.

#7 ONEROA (BOULDER BAY) (1997)

Date: 1 April 1997

Vegetation: Dunes have a relatively open cover of scattered tauhinu/spinifex. Coverage and density of spinifex has increased since 1991, and tauhinu is noticeably more common. Kanuka is increasing; moving into the dunes from the margins of the wetland. Much of these dunes will eventually become low shrubland and then forest (kanuka in the medium term).

#7 ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Dunes towards Boulder Bank—Spinifex runners, scattered tauhinu. Vegetation appears similar to 1990.

#8 ONEROA (BOULDER BAY) (1990)

Date Established: 28 March 1990, 3.50 p.m.

Camera: 35 mm lens

Location: Photopoint on top of dune about 50 m to west of track (about 40 m from #7). View up Hut Valley.

Photo Subject: Kanuka shrubland and pohutukawa in Hut Valley

Photo Information: Tripod height (to base of camera): 1210 mm
Camera angle: flat

Vegetation: Kanuka shrubland on rear dunes/flat and valley sides, pohutukawa forest adjacent to old hut; grassland in valley head.

#8 ONEROA (BOULDER BAY) (1997)

Date: 1 April 1997

Vegetation: Valley floor and lower valley sides all kanuka scrub. Low density of pohutukawa emergent above kanuka, mainly restricted to valley side, but there is one on the valley floor. Lower slopes of Raetihi (Pa Hill) = pohutukawa/kanuka, with some pohutukawa forest in vicinity of the hut.

Valley floor kanuka scrub canopy c. 3–5 m high

#8 ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Kanuka scrub and forest in the foreground, with pohutukawa forest and kanuka scrub in the background. Small area of grassland visible at top of Hut Valley, just below saddle.

#9 ONEROA (BOULDER BAY) (1990)

Date Established: 28 March 1990, 4.10 p.m.

Camera:

Panorama
(a) 35 mm lens, western half Raetihi (Pa Hill)
(b) 35 mm lens, eastern half Raetihi (Pa Hill)

Panorama, no photo-board used
(c) 135 mm lens, western lower slopes Raetihi (Pa Hill)
(d) 135 mm lens, western-middle lower slopes Raetihi (Pa Hill)
(e) 135 mm lens, middle lower slopes Raetihi (Pa Hill)
(f) 135 mm lens, middle lower slopes Raetihi (Pa Hill)
(g) 135 mm lens, middle-eastern lower slopes Raetihi (Pa Hill)
(h) 135 mm lens, eastern lower slopes Raetihi (Pa Hill)
(i) 135 mm lens, eastern lower slopes Raetihi (Pa Hill)

Location: Raetihi (Pa Hill) from boulder bank

Photo Subject: Raetihi (Pa Hill); vegetation pattern

Photo Information: Tripod height (to base of camera):

Camera angle:

Vegetation:
Grassland
Grassland with plantings
Pohutukawa forest
Kanuka shrubland

#10 ONEROA (BOULDER BAY) (1990)

Date Established: 28 March 1990, 4.20 p.m.

Camera:

Panorama, no photoboard
(a) 35 mm, main hill
(b) 35 mm right side of main hill

Location: Main hill from Boulder bank (from same point as #9)

Photo Subject: Main hill, vegetation pattern

Photo Information: Tripod height (to base of camera): 1450 mm

Camera angle: 10° tilt

Vegetation:
Kanuka shrubland
Pohutukawa/kanuka
Kanuka-mahoe
Pohutukawa/'grassland'
Pohutukawa forest on island margins
Some bracken fernland

#9a–i, 10 ONEROA (BOULDER BAY) (1997)

Date: 1 April 1997

Plot No.: 9 a–i; 10

Vegetation: 1. Raetihi (Pa Hill). Left-hand side lower slopes pohutukawa ≤ 4.5 m grades to pohutukawa/kanuka then to kanuka scrub (windshorn low cover). Central area = scattered pohutukawa/kanuka. Upper and right-hand side = pohutukawa forest.

2. Camp valley left hand side = pohutukawa forest, valley floor and right hand side kanuka scrub.

3. Main summit: scattered pohutukawa/kanuka-mahoe. Kanuka dominant on lower slopes, mahoe locally dominant, remainder mixed kanuka and mahoe.

Comments: Need to update vegetation map due to rapid changes in vegetation cover. This will be very useful for future interpretation of photopoints.

#9A ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Pohutukawa forest on western end of island; spinifex grassland on foredune in foreground; pohutukawa forest grades into dense kanuka scrub with occasional emergent pohutukawa. Mamaku is scattered throughout and is locally common in kanuka scrub.

#9B ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: As for 9A above with pohutukawa forest on summit and in Hut Valley. Remainder is kanuka scrub with local mamaku and scattered emergent pohutukawa.

#9C ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Spinifex on duneland with pohutukawa forest on hillslope. Kanuka locally common.

#9D ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Spinifex on sand dunes with pohutukawa forest on hillslopes with kanuka shrubland dominant at the eastern end of the site.

#9E ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Pohutukawa forest on lower hillslopes and western part of site and eastern gully, and kanuka shrubland over much of the midslopes.

#9F ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Pohutukawa forest in gully and upper hillslopes. Kanuka shrubland with occasional emergent pohutukawa on lower slopes.

#9G ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Kanuka shrubland with scattered emergent pohutukawa

#9H ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Pohutukawa forest in gully and kanuka shrubland on hillslopes with pohutukawa commonly emergent.

#10A ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: Mahoe-kanuka forest with occasional emergent pohutukawa

#10B ONEROA (BOULDER BAY) (2002)

Date: 8 January 2002

Vegetation: As for above, with more pohutukawa near summit. Dead kanuka common above fringe of pohutukawa adjacent to coast.

#11 ONEPU (SULPHUR BAY) SADDLE (1990)

Date Established: 29 March 1990, 8.20 a.m.

Camera: 60 mm lens

Location: Photopoint on crest of ridge between Onepu (Sulphur Bay) and Oneroa (Boulder Bay), adjacent to cliff.

Photo Subject: Onepu (Sulphur Bay) saddle

Photo Information: Tripod height (to base of camera): 1450 mm
Camera angle: 15° tilt

Vegetation: Kanuka shrubland 1–2 m high, wind-shaped. Some pohutukawa just starting to emerge through the kanuka. Some pohutukawa at left of photo.

#11 ONEPU (SULPHUR BAY) SADDLE (1997)

Date: 1 April 1997

Comments: No maintenance required. Should put number on photopoint peg.

Vegetation: Kanuka canopy (c. 100%) 1–2 m high with occasional pohutukawa emergent through the kanuka canopy.

Pohutukawa are still establishing in the kanuka scrub

#11 ONEPU (SULPHUR BAY) SADDLE (2002)

Date: 8 January 2002

Vegetation: Kanuka scrub with occasional pohutukawa. There is still a small open area at top of bluff. Vegetation appears similar, although taller.

#12 RAETIHI (PA HILL) POHUTUKAWA (1990)

Date Established: 28 March 1990, 8.30 a.m.

Location: Pohutukawa forest on eastern side of Raetihi (Pa Hill); western side of camp valley saddle.

Photo Subject: Tall pohutukawa forest, grassland, kanuka

Photo Information: Tripod height (to base of camera): 1450 mm
Camera angle: flat

Vegetation: Tall pohutukawa forest, some dead or drying trees, mamaku in gullies. Smaller trees on face to left; kanuka shrubland, and grassland with pohutukawa regeneration.

Notes: From same point as #11

#12 RAETIHI (PA HILL) POHUTUKAWA (1997)

Date: 1 April 1997

Comments: No maintenance required. Put plot number on standard.

Vegetation:
1. Grassland in saddle—now greater density of pohutukawa
2. Former grassland to left side of photo now mainly kanuka
3. Remainder of frame pohutukawa forest

#12 RAETIHI (PA HILL) POHUTUKAWA (2002)

Date: 8 January 2002

Vegetation: **Foreground**—Pohutukawa scrub and patches of kanuka, with limited areas of grassland.

Background—Pohutukawa forest with mamaku in gullies

#13 HUT VALLEY SADDLE (1990)

Date Established: 29 March 2002, 9.00 a.m.

Camera: 35 mm lens

Location: From eastern side of hut valley (100 m from cliff edge) looking into head of valley (to west).

Photo Subject: Grassland with abundant pohutukawa regeneration

Photo Information: Tripod height (to base of camera): 1495 mm
Camera angle: +3°

Vegetation: One large dead pohutukawa on left of photo in gully; some smaller trees on gully rim; grassland sward (predominantly *Microlaena stipoides* and club sedge, some Californian thistle); abundant pohutukawa shrubs in grassland. A few kanuka shrubs present.

Notes: Standard located just above some rocks

#13 HUT VALLEY SADDLE

Date: 1 April 1997

Comments: Put plot number on standard, otherwise no maintanence required. However, some pruning of an adjacent pohutukawa may be required in the future (or move the photopoint 3–5 m).

Vegetation: Change due to increased height and density of pohutukawa. Most 2–3 m, some 1 m and up to 4 m. Also, increasing kanuka among pohutukawa. Will develop (relatively quickly) into pohutukawa/kanuka forest.

#13 HUT VALLEY SADDLE (2002)

Date: 8 January 2002

Vegetation: Pohutukawa-dominant, mostly 3–6 m tall. Limited areas of kanuka and some small patches of grassland in valley floor and on ridge.

#14 MAIN HILL CLIFFS FROM RAETIHI (PA HILL) SUMMIT (1990)

Date Established: 28 March 1990, 9.50 a.m.

Camera: 35–40 mm lens

Location: Cliffs on back of main hill

Photo Subject: Cliffs on back of main hill

Photo Information: Tripod height (to base of camera): 1290 mm
Camera angle: flat

Vegetation: Scattered pohutukawa on cliffs, with denser pohutukawa forest near top of main hill, on northern side. Kanuka shrubland and grassland near top of hill.

Notes:

1. Took two photos with 35 mm lens in panorama from east end of island to Onepu (Sulphur Bay).
2. Photopoint at top of Raetihi (Pa Hill)

#14 MAIN HILL CLIFFS FROM RAETIHI (PA HILL) SUMMIT (1997)

Date: 1 April 1997

Comments: Photopoint was moved 8 m to north; photos taken at old and new points. Should change numbering system on photos in folder.

Vegetation:

Main Summit

1. Relatively open pohutukawa forest on north faces. Upper north faces covered with pohutukawa/kanuka scrub, with scattered pohutukawa lower on faces/*Hebe stricta* (locally abundant).
2. Middle and upper slopes are mahoe-kanuka forest
3. Lower slopes kanuka scrub (2–3 m)

#14 MAIN HILL CLIFFS FROM RAETIHI (PA HILL) SUMMIT (2002)

Date: 8 January 2002

Vegetation:

From Top of Raetihi (Pa Hill)

Main summit: Northern cliffs pohutukawa/kanuka scrub. Main face to west and south is kanuka-mahoe forest with scattered emergent pohutukawa. Kanuka is continuing to establish and infill gaps on the northern cliffs, and to establish to lower levels.

Hand-Held Site/Raetihi (Pa Hill)

(a) Straight down slope: foreground is pohutukawa 1–4 m high with local kanuka and small area of grassland.

(b) Pohutukawa forest with dunes and bouldery coastal margin in background.

#15 EAST SIDE HEAD OF HUT VALLEY (1990) 'Hut Valley Saddle East'

Date Established: 29 March 1990, 11.20 a.m.

Camera: 35 mm lens

Location: Photopoint located adjacent to first large pohutukawa to west of Hut Valley saddle (above 'rat gnaw stick').

Photo Subject: Photo of east side of valley head

Photo Information: Tripod height (to base of camera): 1420 mm
Camera angle: flat

Vegetation: Grassland
Pohutukawa regeneration/grassland
Kanuka shrubland

Notes: No waratah standard marker at this point

#15 EAST SIDE HEAD OF HUT VALLEY (1997) 'Hut Valley Saddle East'

Date: 1 April 1997

Comments: Photopoint site needs to be marked and numbered (c .1–8 m above 3″ × 1″ peg with nail).

Vegetation: Change due to increased height and density of pohutukawa. Most 2–3 m, some 1 m and up to 4 m. Also increasing amounts of kanuka amongst pohutukawa. Will develop relatively quickly into pohutukawa/kanuka forest.

Microlaena stipoides grassland (open area c. 100 × 40 m) c.f. other side of valley = thick cover of pohutukawa. Relatively open area may be due to the combined effect of a well-drained site and high sun exposure. Grassland very thick c.f. pohutukawa previous establishment has been greatest when grass sward relatively open.

#15 EAST SIDE HEAD OF HUT VALLEY (2002) 'Hut Valley Saddle East'

Date: 8 January 2002

Vegetation: Kanuka scrub has increased in extent downslope. Scattered pohutukawa in small patches 3–4 m high. Kanuka scattered amongst pohutukawa. Area of grassland is decreasing.

#16 ONEROA (BOULDER BAY) DUNES (1990)

Date Established: 29 March 1990, 12.00 noon

Camera: 35 mm lens

Location: Crest of ridge between Onepu (Sulphur Bay) and Hut Valley. 400 m from coast.

Photo Subject: Dunes

Photo Information: Tripod height (to base of camera): 1490 mm
Camera angle: –10°

Vegetation: Kanuka shrubland
Duneland with *Spinifex*, tauhinu

#17 OLD HUT FACE (1990)

Date Established: 29 March 1990, 12.00 noon

Camera: 35 mm lens

Location: Crest of ridge between Onepu (Sulphur Bay) and Hut Valley. 400 m from coast.

Photo Subject: Pohutukawa and kanuka on face above old hut

Photo Information: Tripod height (to base of camera): 1490 mm
Camera angle: +10°

Vegetation: Pohutukawa forest
Pohutukawa/kanuka

#16 ONEROA (BOULDER BAY) DUNES, #17 OLD HUT FACE (1997)

Date: 2 April 1997

Comments: Oneroa (Boulder Bay) panorama. Need to mark and number photopoint—currently marked with cruise tape.

Vegetation: Kanuka scrub in valley floor, with occasional emergent cabbage tree and plantings (probably *Coprosma robusta,* kohekohe, akeake).
Two small areas of grassland (*Calystegia soldanella, Microlaena stipoides,* fleabane).
Scattered small stunted kanuka in dune blowout.

#16 ONEROA (BOULDER BAY) DUNES (2002)

Date: 8 January 2002

Vegetation: Increased cover of pohutukawa adjacent to small wetland at back of dunes. Grassy clearings have decreased in area due to encroachment of kanuka. Centre of Boulder Bank now vegetated.

#17 OLD HUT FACE (2002)

Date: 8 January 2002

Vegetation: Kanuka-dominant with patches of pohutukawa forest. Similar to original view in 1990.

#18 HEAD OF SULPHUR VALLEY (1990)

Date Established: 29 March 1990, 12.00 noon

Camera: 35 mm lens

Location: Crest of ridge between Onepu (Sulphur Bay) and Hut Valley. 400 m from coast.

Photo Subject: Head of Onepu (Sulphur Bay)

Photo Information: Tripod height (to base of camera): 1490 mm
Camera angle: flat

Vegetation: Remnant pohutukawa
Kanuka shrubland that has developed following burning
Old charred pohutukawa stems

#18A,B,C PANORAMA DOWN EAST SIDE OF ONEPU (SULPHUR BAY) (1990)

Date Established: 29 March 1990

Camera: 35 mm lens

Location: Crest of ridge between Onepu (Sulphur Bay) and Hut Valley

Photo Subject: See title above

Photo Information: Tripod height (to base of camera): 1490 mm
Camera angle: flat

Vegetation: Kanuka scrub, mixed secondary scrub

#18A MOUTOHORA (1997)

Date: 2 April 1997

Vegetation: All kanuka scrub; a few large remnant pohutukawa. Scattered mingimingi in scrub canopy. Occasional mamaku in canopy as well. Canopy estimated at 2–3 m high. Some cabbage tree seedlings on ridge (on old pohutukawa burn site).

#18A MOUTOHORA (1997)

Date: 2 April 1997

Vegetation: Kanuka scrub with mixed kanuka-mahoe higher on face

PANORAMA ABOVE #18A–C ACROSS EAST SIDE ONEPU (SULPHUR BAY) / SIDE OF MOTU HARA (MAIN SUMMIT) (1990)

Date Established: 29 March 1990

Camera: 35 mm lens

Location: Crest of ridge between Onepu (Sulphur Bay) and Hut Valley

Photo Subject: See title above

Photo Information: Tripod height (to base of camera): 1490 mm
Camera angle: 15°

Vegetation: See 18A,B,C

Notes: Falcon observed being harassed by small flock of swallows

#18B MOUTOHORA (1997)

Date: 2 April 1997

Vegetation: Kanuka scrub with occasional mahoe higher up. Scrub taller (3–4 m?). Some kanuka dead—thinning out.

#18C MOUTOHORA (1997)

Date: 2 April 1997

Vegetation: As for 18b, with large pohutukawa on bluff edge. Top left of photo lower canopy of kanuka.

#18A MOUTOHORA (2002)

Date: 8 January 2002

Vegetation: Kanuka-dominant scrub, with some dead kanuka. One small rewarewa emergent above kanuka.

#18B MOUTOHORA (2002)

Date: 8 January 2002

Vegetation: Kanuka-dominant scrub, some kanuka are dead. One small rewarewa emergent above kanuka.

#18C MOUTOHORA (2002)

Date: 8 January 2002

Vegetation: Kanuka-dominant forest with dead kanuka common and scattered pohutukawa amongst kanuka. Strip of pohutukawa forest adjacent to coast.

#18D MOUTOHORA (1997)

Date: 2 April 1997

Vegetation: Lower scrub
Upper kanuka-mahoe

#18D MOUTOHORA (2002)

Date: 8 January 2002

Vegetation: Left hand side of main high point. Mahoe-dominant forest with kanuka common.

#18E MOUTOHORA (1997)

Date: 2 April 1997

Vegetation: As for 18d. Upper section now pohutukawa/kanuka-mahoe (top right section previously scattered pohutukawa/grassland).

#18E MOUTOHORA (2002)

Date: 8 January 2002

Vegetation: Patches of mahoe forest and kanuka forest with scattered pohutukawa (locally dominant near summit).

#19 BOULDER – ONEPU (SULPHUR BAY) RIDGE WEST SIDE (1990)

Date Established: 29 March 1990

Camera: 35 mm lens

Location: Crest of ridge between Onepu (Sulphur Bay) and Hut Valley. 400 m from coast.

Photo Subject: Ridge crest looking towards coast(s)

Photo Information: Tripod height (to base of camera): 1490 mm
Camera angle: –15°

Vegetation: Kanuka scrub. A few pohutukawa in background adjacent to coast.

#19 BOULDER – ONEPU (SULPHUR BAY) RIDGE WEST SIDE (1997)

Date: 2 April 1997

Vegetation: Kanuka scrub. Very stunted and open on ridge (≤ 1 m high, some only 0.5 m)—other species present include *Cyathodes juniperina,* mingimingi*, Morelotia affinis,* pohutukawa. Pohutukawa seedlings commonly establishing on ridge line—open sites common. Will eventually develop into pohutukawa/kanuka forest.

Scrub canopy height increased to 2–3 m on sides of ridge (nearly pure kanuka, occasional mingimingi in canopy).

#19 BOULDER – ONEPU (SULPHUR BAY) RIDGE WEST SIDE (2002)

Date: 8 January 2002

Vegetation: Western side of Onepu (Sulphur Bay) – Oneroa (Boulder Bay) ridge. Kanuka-dominant scrub with patches of kanuka-mingimingi scrub. Occasional pohutukawa.

'HAND-HELD SITE 1–3' MOUTOHORA (1997)

Date Established: 1 April 1997

Location: Lower slopes of Lower Raetihi (Pa Hill), looking south

Subject: Pohutukawa and dunes at Oneroa (Boulder Bay)

Plot No.: HH1-3 (Lower Raetihi (Pa Hill)); W15/370, 371, 372

Vegetation: 1. Abundant pohutukawa/kanuka regeneration on lower slopes. Club sedge common with some local areas of grassland dominated by *Microlaena stipoides* with Yorkshire fog*,* plume grass*,* fleabane. Strip of grass on ridge line; remainder mostly pohutukawa and kanuka. Pohutukawa 1–3 m / kanuka ≤ 1 m. Small patches of grassland among treeland.

2. Dunes with scattered spinifex cover

3. Wetland at rear of dunes with abundant *Cyperus ustulatus.*

Appendix 2

EQUIPMENT REQUIRED FOR PHOTOPOINT REMEASUREMENT

1. Safety and communication equipment
2. Map showing photopoint locations
3. Reference set of site photographs
4. Copies of original photographs
5. Copies of photographs taken in previous year
6. Camera, shutter release, tripod, film(s)
7. Photoboard, pole, and pens (to note site details and date), and cleaner for board
8. Spare tags for site markers, and aluminium wire
9. Photopoint record sheet, notebook(s), pencils/pens
10. GPS unit and site coordinates
11. Binoculars
12. Field notebook and pencils

Appendix 3

PHOTOPOINT PHOTOGRAPHS