Sand Dunes of the Murihiku District
Priorities for Restoration

Prepared for the Department of Conservation, Murihiku District

By

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Cover Photo: Tahakopa Bay, June 2015

Executive Summary

This report provides a summary of the conservation values and restoration potential of dune systems in the Murihiku District, with a particular focus on the Catlins district. Five questions are addressed:

- which dune systems continue to exhibit active dune processes?
- which dune systems should be prioritised for restoration management, based on existing ecological integrity?
- what are the most appropriate management options for priority restoration sites?
- is it practical to improve New Zealand sea lion habitat at Cannibal Bay and Surat Bay; in particular, is it realistic to modify foredune morphology to improve habitat for pupping and female haul-out?
- are there other sites in the Catlins district that should be considered for New Zealand sea lion conservation – primarily sites for pupping and female haul-out?

Sand dunes in the Murihiku District were assessed using a combination of site visits, analysis of aerial and satellite photography, and published data. Field work was conducted between the May 29th and July 20th 2015, with site visits made to 12 of the 21 dunes in the District. The botanical and geomorphic values and key threats to these values were identified at each dune system.

Dunes in the Catlins district (the coast between the Clutha River Mouth and Toetoes Harbour Mouth) retain a high degree of wilderness. These dunes have escaped the direct impacts of urbanisation and exotic afforestation common in many regions of New Zealand. However, invasion by non-native plants (namely marram grass, tree lupin, and gorse) has caused substantial ecological modification to these dunes. In particular, there has been a major loss of botanical values as these exotic species displace native species. All dune systems in the Catlins district are dominated by non-native plants, but significant populations of native dune species are retained at several sites; Surat-Cannibal Bay, Tahakopa, Tautuku, Long-Dummies Beach and Waipapa Beach. At most sites the native dune species are restricted to areas where non-native plants, particularly lupin, are not yet dominant. Invasion is ongoing at all sites and it is inevitable that the dune systems of the Murihiku District will be completely dominated by weeds without active management. The opportunity for effective management at priority sites is fast closing. Pīngao is present at Tahakopa and Waipapa but has almost succumbed to resurgent tree lupin, although there is still time to save the existing wild populations.

Dunes in the Southland region (Toetoes Harbour Mouth to Port Craig) have been modified by invasion of non-native plants and conversion to farmland. Only two dune systems retain exceptional conservation values — Fortrose Spit and The Three Sisters. Both sites are of national conservation and scientific significance, with outstanding botanical and geomorphic

values. These values have been retained at Fortrose Spit because of ongoing restoration actions undertaken by the Department of Conservation (DOC), primarily weed control. Some conservation works (weed control, fencing) have occurred at The Three Sisters in the past; however the exceptional values at this site remain threatened by the ongoing spread of non-native weeds and will be lost over the next 20 years or so without management.

Tahakopa Beach, Tautuku Bay, Waipapa Beach, Fortrose Spit and The Three Sisters should be the focus of future dune restoration in the Murihiku District. Restoration activities at all sites will largely involve weed control, although re-planting pīngao and other species might be considered where native dune species have been displaced. Lagomorph control and restrictions of ATV access will also be required at some sites.

All restoration works will be long-term projects, spanning decades, because of regeneration of target species from seedbanks. Marram can also reinvade from marine-dispersed rhizome. Procedures to regularly monitor the decline in target weed species and the recovery of the desired ecosystem values are essential. Biannual or annual technical meetings of involved parties (technical support, managers, field rangers and university staff) have proved essential to the development of dune restoration projects on Stewart Island and should be implemented here. We also recommend that this report is followed by a meeting of DOC staff (including technical support staff) and the authors of the report to discuss the recommendations. Site visits to selected dune systems at this time would be beneficial, particularly Tahakopa, The Three Sisters and Fortrose.

Sand dunes in the Catlins district provide good habitat for sea lions. Most beaches retain areas where sea lions are able to access the dunes, albeit coastal erosion currently limits access to inland dune areas along most sections of coast. Dune forms along selected coasts could be modified to improve access, particularly at Surat-Cannibal Bay. Overall, however, habitat is not currently limiting population growth given the low numbers of sea lions on the mainland New Zealand coast. Restrictions in dune access may become more problematic as mainland sea lion populations increase. Implementation of an adaptive management plan to determine the implications of restricted dune access on breeding females and to mitigate any adverse effects could be considered.

Contents

1.0 Introduction

Coastal sand dunes are one of New Zealand's most threated environments. Widespread grazing and burning of dune areas during the late 19th and early 20th centuries resulted in a decline in native dune vegetation and an associated increase in dune mobility. Since the late 1880s stabilisation and afforestation of sand dunes, sand mining, stock grazing, infrastructure development, urbanisation and the spread of a wide range of exotic plant species have contributed to the widespread degradation of New Zealand's coastal dunes. The area of sand dune now is less than 30% of its extent in 1950, and most of the remaining dune systems have lost geomorphic function and associated biodiversity (Hilton et al 2000; Hilton 2006). Dunes retaining vegetation communities that are dominated by native species are rare, and much of the flora and fauna endemic to the dune environment is now nationally rare, threatened or endangered. The remaining values at all sites, no matter how isolated, will be lost without active and sustained management.

Much of the physical and ecological character of New Zealand's sand dunes is due to the ongoing or very recent movement of sand by wind. Small dune systems typically comprise a single set of landforms, often incipient foredunes and foredunes (shore parallel ridges of sand that form the most seaward dunes), whereas larger dune systems support a wide range of dunal environments and associated landforms. These include foredunes; vegetated and semi-vegetated parabolic dunes; sand sheets (usually associated with high rates of sand movement); scrub growth on recently stabilised substrate; deflation surfaces; moist dune slacks and wetlands; coastal turf on a range of substrates including rocky outcrops within larger active dune systems; and dune lakes.

These active dune systems are distinct from older dune landscapes, that typically show advanced soil development, which may have a mature podocarp forest cover (or were forested prior to agricultural development). These older landscapes may be comprised of strand plains of relict foredunes or stabilised transgressive dune systems. The distinction between these two types of dune landscape can be blurred where recently active dune systems, mobile to the early to mid-20th century in some cases, have been stabilised as a result of introduced species (primarily marram grass (*Ammophila arenaria*)). Such systems may retain characteristic dune flora for a time, but have lost their distinctive dynamism. They are, however, capable of restoration if successional processes are not advanced, and such sites are included in this survey.

The protection of indigenous vegetation associated with sand dunes is recognised as a National Biodiversity Priority (Ministry for the Environment 2007). New Zealand sand dunes contain grasses, sedges, herbs and low shrubs, many peculiar to the dune environment and dependant on sand mobility for survival. Dune species display high regional and/or national endemicity. Mobile and semi-mobile sand dunes also support nationally significant wildlife species. They provide nesting sites for shorebirds (New Zealand dotterel (*Charadrius*

obscures), banded dotterel (*Charadrius bicinctus*), variable oystercatcher (*Haematopus unicolor*)); habitat for a wide range of insects, most famously the katipo spider (*Latrodectus katipo)*; and haul-out and breeding sites for the New Zealand sea lion (*Phocarctos hookeri*). This biodiversity is closely linked to the quintessential dynamic nature of coastal dunes, since habitat for these species depends on sand moment and dune development. Dune development results in topographic and environmental diversity (hence habitat diversity) and frees dune-adapted species from competition from weeds and opportunistic native species.

This report provides a summary of the conservation values and restoration potential of dune systems in the Murihiku District, with a focus on the Catlins district. The Sand Dune and Beach Vegetation Inventory (henceforth 'the Inventory'), conducted by the Botany Division of the former Department of Scientific and Industrial Research (Johnson 1992), provides the only systematic assessment of coastal dunes in this region to date. Based on field surveys conducted between 1984 and 1988 the Inventory ranked beaches and sand dunes in the Murihiku District based on the diversity of landforms and communities, the dominance of native sand dune plant species, and degree of modification of the site. Five dune systems were identified as national priorities for conservation; Tahakopa, Tautuku, Waipati, Long-Dummies Beach and Fortrose Spit — Toetoes Harbour Beach. A further 9 beaches with significant dune systems retained significant conservation values; Surat-Cannibal Bay, Waikawa Harbor, Waipapa Beach, Waipapa Point, Tiwai Beach, Three Sisters Dune, Howells Point, Colac Bay, and Kawakaputa Bay. The main threats to these systems were identified as grazing and invasion by non-native plants. More recent reports have considered the geomorphic and ecological state of specific dune systems (e.g., Hilton 2000; Rance 2006; Bythell and Rance 2014). It is timely to provide a synoptic overview of dune system values and restoration opportunities while values and opportunities for restoration remain.

This report considers:

- which dune systems continue to exhibit active dune processes?
- which dune systems should be prioritised for restoration management, based on existing ecological integrity?
- what are the most appropriate management options for priority restoration sites?
- is it practical to improve New Zealand sea lion habitat at Cannibal Bay and Surat Bay; in particular is it realistic to modify foredune morphology to improve habitat for pupping and female haul-out?
- are there other sites in the Catlins district that should be considered for New Zealand sea lion conservation – primarily sites for pupping and female haul-out?

2.0 Study Area

The Murihiku coastline extends from the Clutha River mouth in the north to Port Craig in the southwest (Figure 1). The Catlins district includes the coast from the Clutha River Mouth in the north to the Toetoes Harbour Mouth in the south. The sand dunes of the Catlins district are located within the Tahakopa Ecological District (McEwan 1987). Dune systems along the southland coast west of the Toetoes Harbour Mouth (henceforth the 'Southland Region') are located within the Waituna, Foveaux, Southland Plains, and Longwood Ecological Districts (McEwan 1987). Several dune systems within the Murihiku District are administered by the Department of Conservation (DOC) including Surat-Cannibal Bay, Tahakopa, Waipapa Beach, Haldane Beach, Fortrose Spit, and Kawakaputa Beach.

The Murihiku District contains a remarkable diversity of coastal landforms and environments, quite exceptional at a national scale, that reflects variation in geological structure (and coastal physiography), wind strength and direction, sediment type and supply and coastline orientation. In general terms it is a headland-bay coastline, characterised by alternating headlands and bays containing coastal barriers. There is a concomitant diversity of coastal barriers and associated sand dune systems. Here the term 'barrier' refers to wedges of sand (or other sediments) deposited within embayments, during the last post-glacial marine transgression and during the present sea-level stillstand. In other words, sand

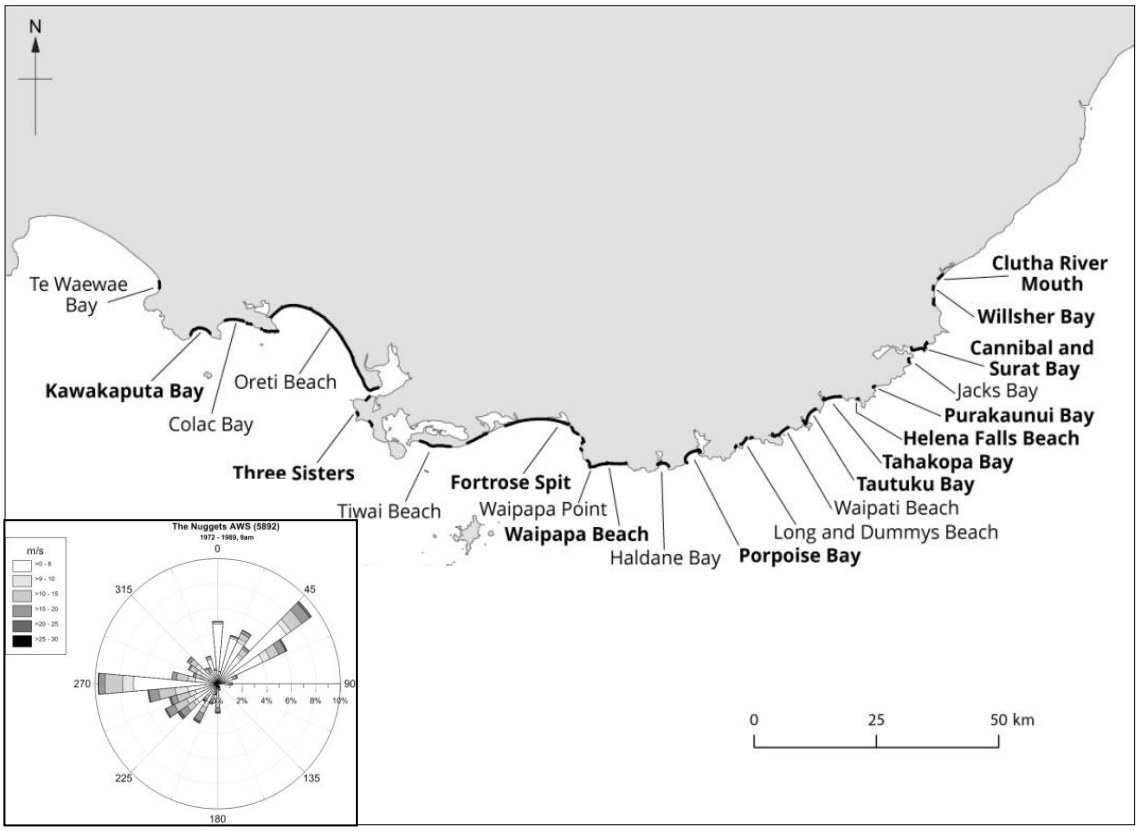

Figure 1. Location of the dune systems in the Murihiku District. Sites visited are in bold. The inset shows the wind rose for the Nuggets weather station.

transported shorewards and onshore over the last 10,000 years or so. Sand may also accumulate behind the barrier as estuarine, lagoon or saltmarsh deposits. In the aggregate, these deposits are termed a 'barrier' by geomorphologists. A range of morphologies are recognised in the classification of Cowell & Thom (1994) based on morpho-stratigraphic investication of the barriers of east-coast Australia (Figure 2.)

The surface processes and morphology (or form) of the barrier depend on a number of factors, including the rate at which sediment is delivered ashore, the presence or not of rivers (and the input of fluvial sediments), the size and shape of the embayment in which sediment is deposited, and the exposure of the embayment to those processes that transport sediment. A distinction is drawn here between barriers that have prograded (built seaward) by the incremental addition of foredunes or beach ridges and barriers that are characterised by transgressive dunes.

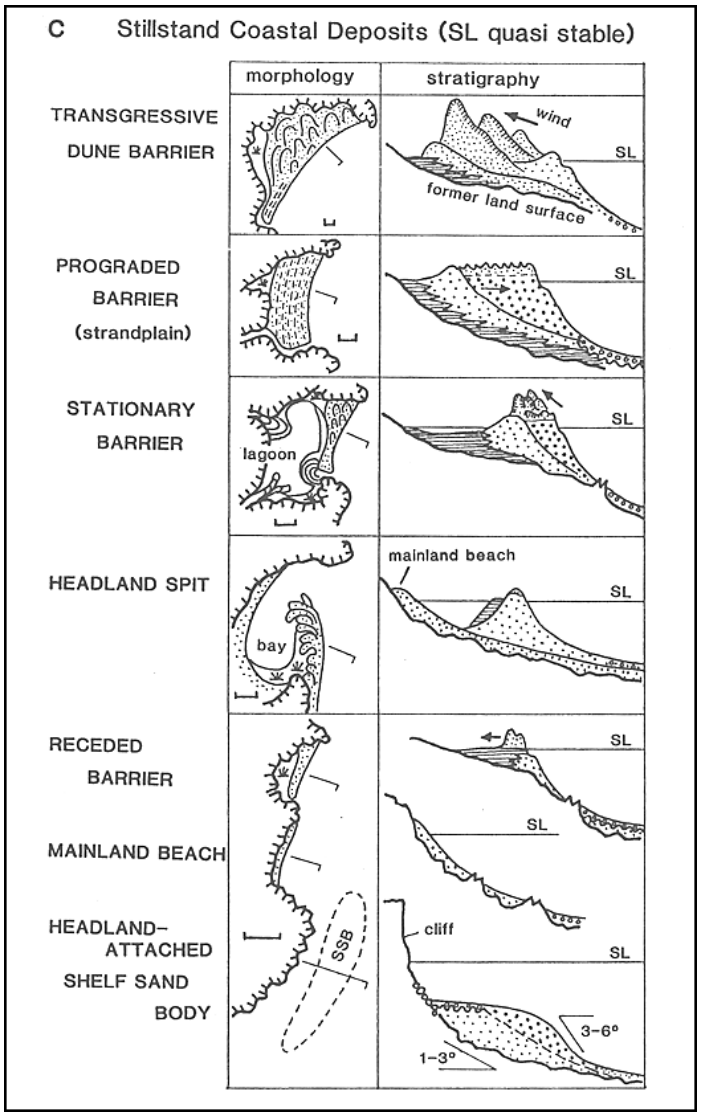

Figure 2. Barrier morphologies (Cowell and Thom, 1994). Coastal barriers in the Murihiku District are primarily transgressive dune barriers, prograded barriers and headland spits.

A **prograded foredune barrier** is more likely to develop on a sheltered (from winds) lee coast, because the potential for blowout and parabolic dune development is much reduced. The term 'prograded foredune barrier' refers to a spatial sequence of foredune ridges deposited through time. One can visualise such a sequence as a number of sausages laid side by side. The resulting topography, in section, comprises a ridge and swale topography. The swales result from a disruption in sand supply to the foredune, from the adjacent beach, following storm events and foredune scarping. The height and spacing of the foredune ridges is related to the rate of sand supply, the frequency of storm events and the presence and type of sand-binding vegetation. The primary southern sand-binding species, *Ficinia spiralis* (pīngao), tends to form low, widely-spaced, foredunes, although there are exceptions. Finally, in most cases the most seaward margins of these barriers have been disturbed by blowout development, which may be cyclic. These cycles have resulted in higher and wider foredunes, particularly where the pīngao has been replaced by marram grass, which both stabilises and destabilises dunes.

Excellent examples of prograded foredune barriers occur in the study area – including the exceptional forested barriers of the Catlins core (Tautuku, Tahakopa and Waipati) and the devegetated barriers of Surat and Cannibal Bay. Tahakopa provides a good example of foredune development adjacent to the coast. These barriers have ceased prograding (building seawards) and are in a dynamic equilibrium state. That is, they tend to prograde and erode about a mean shoreline position (albiet the recent trend at Tahakopa is one of erosion). This dynamic tends to favour foredune accretion (vertical growth) and lateral development, since periods of disturbance may result in minor, localised, blowout development. Such development seldom extends far inland, however transgressive dunes can also form on prograded barriers following substantial dune disturbance (e.g. natural or human-induced de-vegetation) where barriers are exposed onshore winds. Surat-Cannibal Bay, for example, contains examples of recent transgressive dunes migrating over an older prograded foredune barrier. Prograded foredune barriers within the Murihiku district are commonaly associated with river mouths and estuaries.

Transgressive barriers occur in embayments that are significantly more exposed to onshore winds. In the study area these occur on the Fouveux Strait coast and south of Curio Bay. These stretches of coast are exposed to westerly winds that strike the coast at a range of angles, depending on the orientation of the shoreline relative to these winds. For example, north of Waipapa Point these winds cross the shoreline and drive sand inland almost normal to the shoreline. East of the same headland the westerly winds drive sand alongshore towards and over Slope Point, spilling sand into the bay further east. This pattern repeats in Haldane Bay – or used to repeat prior to dune stabilisation – where sand is driven alongshore over the headland into Curio Bay. This is a very distinctive geomormology preculiar to the Southland Region. Unfortunately no pristine examples remain.

The Three Sisters dune system is the last remaining example of an active transgressive barrier in the study area. It has added interest as a '**climbing transgressive dune system'**, basically a transgressive dune system comprised of parabolic dunes migrating inland and over hill country. The typical elements of a parabolic dune are difficult to recognise because dune development is modified by the general topography and rock outcrops – but the elements of parabolic dunes (deflation surfaces, marginal trailing arms and depositional lobes) are recognisable. The threats to this dune system are discussed in the main body of the report. Its long term conservation requires control of marram grass and other weed species.

The barriers of Kawakaputa Bay, Colac Bay and Oreti Beach contain both progradational and transgressive barriers. These barriers occur in a series of embayments adjoining Foveaux Strait. Wind flow is strongly west to east, creating sections of each barrier that are relatively sheltered (western section) and relatively exposed (eastern section). Foredune sequences tend to be preserved in the former, whereas parabolic dune development occurs east of the shelter afforded by the western headland (Figure 3). Whether the latter is natural, arising for destabilisation of the foredune sequence, or associated with Maori occupation or European settlement, is difficult to determine. Transgressive dune development in Kawakaputa Bay, and possibly Colac Bay, and disruption of the south coast rail line, occurred in the late 1800s and was in part the catalyst for the enactment of the Sand Drift Act 1908.

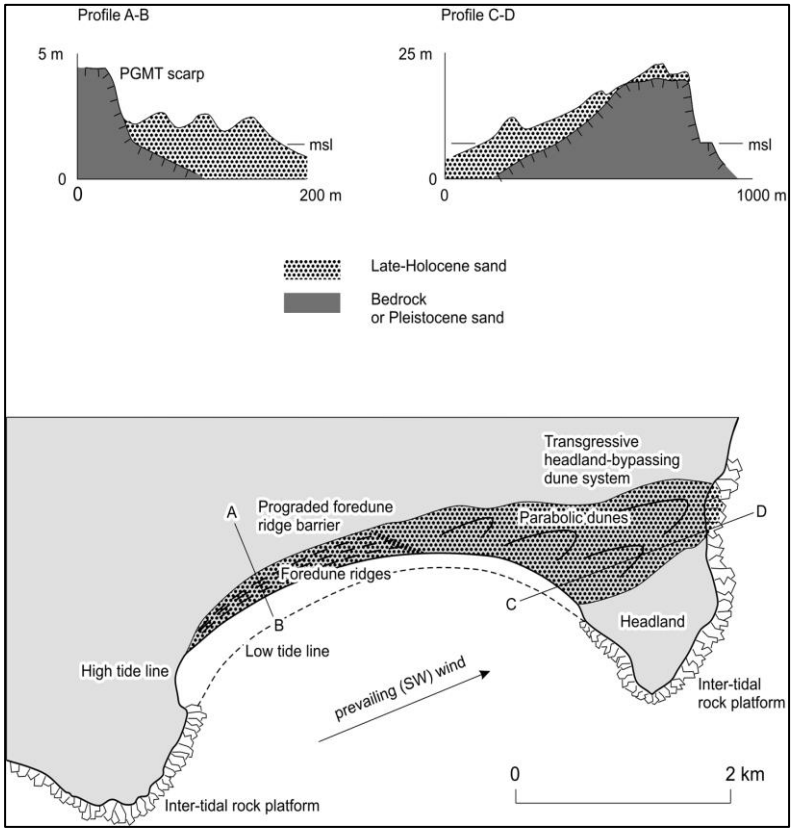

Figure 3. A schematic summary of a complex prograded foredune - transgressive barrier, typical of the Fouveux Strait barriers.

Two other barrier types are worth mentioning. Very little is known about the Awarua Barrier, although GNS have noted the very wide sequence of ridges (approximately 2000m that are likely gravel ridges. These are 'beach ridges', rather than foredune ridges. The distinction is important. In the case of beach ridges the sediments comprise shell or gravel and are wave deposited. The elevation of the ridges is, therefore, closely coupled with sea level (the elevation reached by breaking waves during storm events). In contrast foredune ridges may be many metres above storm-tide level, since sand can be blown many metres inland and above the beach. The Awarua is an exceptional example of this type of barrier, but it has unfortunately attracted very little research. It is likely to be of very high scientific value. We are uncertain about the sedimentology and morphology of the coastal margin of this barrier – which may contain some proportion of sand and which has almost certainly been modified by marram grass.

Secondly, Fortrose Spit is an excellent example of a type of **headland spit** – albeit in this case the "headland" is the Awarua Barrier. We know relatively little about this coastline, but it seems there is an alongshore gradient in sediment texture, from coarse to fine, from west to east. Hence Fortrose Spit is comprised of relatively fine to medium sands that are easily transported by winds. The height and mobility of the dunes on Fortrose Spit increases east of the whitebait shacks, which is partly a function of the availability of fine sediments, but also the increasing exposure of this length of the coast as it curls to the east and towards the mouth of the Mataura River. New Zealand contains many sand spits but Fortrose Spit is distinctive in possessing extensive deflation surface cushionfield communities, which have very fortunately been managed by DOC. The height and morphology of the dunes east of the management zone is likely to be the result of marram grass invasion, at least in part.

The coastal vegetation of the Murihiku District is distinctive. The Southland and Stewart Island coast is a "biodiversity hotspot" known to support at least 13 local endemic species, 9 of which are species peculiar to beach and sand dune habitats (including 8 nationally threatened or uncommon species). A total of 26 Nationally Threatened and At-risk plant species have been recorded from dunes within the Murihiku District (Appendix 3). This flora includes two Nationally Threatened species; eleven At Risk-Declining species; eleven At Risk-Naturally Uncommon species; and two Data Deficient species. Many species have a limited distribution, restricted to only one or two sites within the Murihiku District (Appendix 3). Sand dunes in the District also support a significant fauna, particularly New Zealand sea lions.

In summary, the Murihiku District contains many exceptional coastal landforms – namely the forested prograded foredune barriers (e.g. Tahakopa); Awarua Barrier (prograded beach-ridge barrier); Fortrose Spit (headland-spit barrier); and The Three Sisters (transgressive barrier). To date these features, have attracted very little scientific attention, despite their regional and national geomorphic significance and associated ecological values.

3.0 Methodology

Sand dunes in the Murihiku District were assessed using a combination of site visits, analysis of aerial and satellite imagery, and published data. These include DOC publications, plant species lists, and research projects undertaken by staff and students from the University of Otago. First-hand accounts of specific dunes were also obtained from DOC staff, and through author experience gathered over the past twenty years. Accounts of the habitat requirements of New Zealand sea lions were obtained from DOC, the New Zealand Sea Lion Trust, and research projects undertaken by staff and students from the University of Otago.

Site visits were made to 9 out of 14 dunes in the Catlins district and 3 out of 7 dunes in the Southland region. Dune systems with known ecological or geomorphic values (or where recent aerial photography indicates a moderate to high restoration potential) were prioritised. Brief site visits were also made to dunes which were known to be degraded, but which could be easily accessed. Waipati Bay and Long-Dummies Beaches could not be accessed due to adverse weather; but these sites had been visited previously. Evaluation of these sites was based on aerial photographs and existing plant species lists. Haldane Bay and Kawakaputa Bay had been recently examined (Hilton 2000), and further field work here was not required.

Field work was conducted between the 29th May and the 20th July 2015. The biota and geomorphology of each dune system was examined. We also sought to identify key threats to these systems (including weeds, vehicles, and lagomorph browse). The dominant dunal landforms were described and mapped. The current shoreline position was mapped using a handheld GPS and this data overlain on geo-referenced aerial photographs (dating from the 1940s). These comparisons allow medium term erosion/progradation trends to be identified and provided evidence of historic changes to back beach sea lion habitat to be quantified.

Additional survey detail is provided in the following sections. In general, dune systems were prioritised for restoration management based on the following criteria:

- the condition of the dune system (i.e., level of modification, presence and significance of threat, retention of native dune plants).
- the ecological and geomorphic diversity of the dune system.
- the ecological setting (i.e., is the dune backed by intact native forest vegetation, wetlands, and/or lagoons allowing sequences of habitats to be restored?).
- the presence of uncommon dune features (i.e. rare landforms, threated plant species).

The practicalities of undertaking restoration works were also considered. For example, is the land administered by DOC? Is restoration work already underway? Is there good access to the site? Is the site conducive to restoration works (weed control, for example)? Is the

potential restoration area well defined? That is, is the dune system bounded by landforms or plant communities resulting in a distinct area where restoration could be undertaken? Fortrose Spit, for example, is a distinct landform bounded on three sides by water. Is the site accessible or used by the public and is there scope for dune conservation advocacy? These considerations are additional to the criteria listed above, but are used to discriminate dune systems with similar ecological and geomorphic values.

Evaluations of the Murihiku dunes are provided in Appendix 1. These include a description of each dune systems, identification of key threats and values, and the potential for restoration. Appendix 2 contains maps of those dune systems visited.

4.0 Results

4.1 The Catlins District

Sand dunes on the Catlins coast retain a high degree of wilderness with little direct modification by people. This quality is shared with only a few other regions of New Zealand, namely Stewart Island, Fiordland and the Far North district of the North Island (Hilton 2006). Past gold mining activities and grazing have altered dune landforms at a few sites (e.g. Waipapa Beach) but these effects are relatively minor.

The prograded foredune barriers of the Catlins core (Tahakopa, Tautuku, Waipati) are exceptional examples of this barrier type. They are of national significance due to their size and geomorphic and ecological integrity. The retention of successional vegetation sequences from recently stabilised dune-vegetation though to late successional coastal forest is uncommon nationally, and the presence of three adjacent barriers retaining these vegetation sequences is a significant 'value' of the Catlins coast. While the ecological and geomorphic integrity of the most recently active dunes along the seaward margins of these barriers has declined following the invasion of non-native plant species, Tahakopa and Tautuku retain significant populations of rare and threated native dune plants (Appendix 3). Waipati Beach was not examined in the field but is likely also to retain some native dune plant species.

The transgressive barriers of the Catlins coast are of geomorphic significance (Cannibal-Surat, Porpoise Bay, Haldane Bay, Waipapa Beach), namely as a record of environmental change along the south east coast of New Zealand, but retain few ecological values. The exceptions are the Surat-Cannibal Bay tombolo and Waipapa Beach both which retain significant populations of native dune species, particularly those associated with damp depressions and dune slacks (Appendix 3). The dune slack area at Waipapa Beach in particular, although originally formed by gold dredging, is the largest dune slack in the Southland region and is likely to be nationally significant.

The remaining dune systems of the Catlins coast are small. They have little geomorphic complexity and retain few ecological values. The exception is Long-Dummies Beach which retains pīngao and contains the only population of *Euphorbia glauca* in the Catlins district.

All dune systems in the Catlins area have been modified following the invasion of non-native plants. Marram grass and *Lupinus arboreus* (tree lupin) are widespread throughout the Catlins dunes and form the dominant vegetation cover at most sites. Other weed species present but not yet dominant include *Ulex europaeus* (gorse) and *Hieracium* spp. Grazing by stock (e.g. Long-Dummies Beach) and/or lagomorph browse (e.g. the southern end of Tautuku Bay) pose additional issues in some dunes.

Marram grass stabilises mobile dune surfaces and forms foredunes that are more massive, higher and steeper than those associated with native dune species (Esler 1970; Hilton *et al.* 2005). Sand mobility and associated geomorphic processes are almost absent where marram is present. Coastal progradation (the advance of the land seawards) and the concurrent narrowing of the beach often follows marram invasion in southern New Zealand. The native dune flora is typically displaced during this period of accelerated dune building. The impact of tree lupin in coastal sand dunes is both physical and biochemical. Lupin is a nitrogen-fixing species and invasion of dune ecosystems by lupin is associated with increases in soil nutrient availability, facilitating the invasion of other non-native species. These effects have proved to be persistent in stable dune environments, remaining for several years following the removal of lupin (Konlechner *et al.* 2015). The effects of gorse in coastal dunes are similar to those associated with lupin invasion.

Plant invasion by marram grass and tree lupin in sand dunes follows a well-documented sequence: 1) the colonisation and subsequent stabilisation of dunes by marram; 2) invasion of the stabilised dunes by lupin; 3) nitrogen enrichment of soil and associated soil development by lupin; and 4) growth of exotic grasses and other ground cover species. Accordingly, dunes are converted from sparsely vegetated and mobile systems dominated by native dune species to densely vegetated shrub communities via a series of invasive stages. The ecological and geomorphic integrity of dunes on the Catlins coast has declined in this manner.

In general, the more advanced the invasion sequence and the longer an invasive species has been present in an area, the greater the degree of geomorphic and ecologic modification. For this reason we consider the spread of tree lupin to be the greatest threat to the remaining botanical values of the Catlins dunes. Marram is widespread through all the dune systems visited, has been present at most sites since at least the 1960s, and occupies close to all available habitat forming an almost continuous plant cover in most cases. While lupin occupies a large portion of the dunal areas of many sites through the Catlins district, it is yet to occupy all available habitat at several sites. Tahakopa, Tautukua and Waipapa Beach, for

example, all retain areas that remain, at present, free from lupin. Further, some native dune plant species, for example *Pimelea lyalli* and *Coprosma acerosa*, appear to co-exist with marram in certain circumstances. In all cases, however, we found no native dune plant species where tree lupin formed a dense canopy. This is most apparent at Tahakopa where a significant decline in pīngao population since 1999 correlates with the spread of lupin (Figure 4); and at Tautuku and Waipapa Beaches where native dune plants were found only where lupin was absent or sparse.

The invasion of lupin is ongoing. We observed areas of seedlings and juvenile plants on the margins of established populations at most sites. Analysis of aerial photography indicates

Figure 4. Decline in pīngao and increased dominance of tree lupin between 1996 and 2010, Tahakopa Bay. Photo: M. Hilton.

that the area occupied by lupin has increased considerably over the past 20 years. Limiting the further spread of lupin will be critical in protecting the remaining conservation values of the Catlins dunes. Other non-native weed species (e.g. gorse, *Hieracium* spp) are also likely to be extending their distribution.

We recorded relatively few indigenous dune plant species. Pīngao was notably absent from most dunes with only 20-30 scattered plants found at Tahakopa and a single plant at Waipapa Beach. Pingao is also reported to be retained at Long-Dummies Beach, but is threatened by stock (M. Hilton, pers. comm.). Most plants observed at Tahakopa and Waipapa Beach were moribund with low vigour, although a few were flowering (Figure 5). All were overgrown with marram and or tree lupin. These plants will need to be the focus of dedicated (and urgent) conservation efforts if they are to survive. There are significant remnant populations of other indigenous dune plant species at Surat-Cannibal Bay, Tahakopa Bay, Tautuku Beach and Waipapa Beach; including several threated and at risk species (*P. lyalli*, *C. acerosa*, *Raoulia* spp., *Geranium sessiliflorum var. arenarium*, *Libertia peregrinans* for example) (Appendix 3). For some species this survey was the first record of these species at some sites (e.g., *L. peregrinans*, *C. acerosa*, *G. sessiliflorum var. arenarium* at Tahakopa; Appendix 3). With the exception of *P. lyalli* and *C. acerosa* these are restricted to a few small (<20m^2) areas where the vegetation cover remains sparse. As with pīngao, these plants will need active conservation to survive. Significant dune slack plant communities are also present at Surat-Cannibal Bay and Waipapa Beach.

Figure 5. A remnant pīngao plant at Tahakopa Bay (June, 2015). The size and vigour of this plant, and the environmental setting and competition with exotic species are typical of other pīngao plants at Tahakopa and Waipapa Beach.

Many of the dune systems visited lacked a foredune. In many instances the coastal margin is manifest as a high erosional scarps cut into the foredune (or barrier where no foredune is present) (Figure 6). A large portion of the dunes at Tahakopa, for example, have been lost in recent years and the dune margin has exhibited an erosional character for the last 20 years. At some sites this phenomenon is likely to be the consequence of coastal progradation following with marram invasion. Coastal erosion has occurred more frequently as the coastline has prograded. This has implications for penguins and sea lions. The dune scarp at the northern end of Surat Bay, for example, must now limit sea lion access to the dunes.

Figure 6. Recent dune scarping at; A) Waipapa Beach to west of the Lake Brunton outlet; and B) the northern end of Surat Bay. Photos taken in June 2015.

4.2 The Southland Region

Most dunes on the Southland coast have been substantially modified by the invasion of non-native plant species, particularly marram grass and tree lupin, and/or conversion to agricultural land. Many of the transgressive barriers that are characteristic of this coastline are now stable and geomorphic processes are almost absent (e.g. Kawakaputa Bay, Colac Bay, Oreti Beach). Marram, lupin, gorse and other woody species have been controlled by DOC within a 30ha area (24% of the dune system) at Fortrose Spit since the late 1980s (Bythell and Rance 2014). Limited weed control occurred at The Three Sisters in the 2000's targeting marram, gorse and Spanish heath, a fence constructed along the southern boundary and the dune destocked. To our knowledge no management has occurred at other dunes sites in the Southland region.

Native dune plants were observed at only two sites — Fortrose Spit and The Three Sisters. These sites are exceptional, not just in the Murihiku District, but also nationally. They retain the largest populations of pīngao in southern New Zealand outside Fiordland and Stewart Island, as well as other significant native dune plant species (Appendix 3). The Three Sisters site in particular supports a significant dune flora. It is the only mainland Southland site retaining the nationally critical *Gunnera hamiltonii* (one of only seven *G. hamiltonii* plants known). The Three Sisters site is suspected to be the type locality for this species. Further The Three Sisters Site supports the greatest number of threated plants in the Murihiku District (21 taxa), and is the only site in the Murihiku District for several species in addition to *G. hamiltonii* (Appendix 3).

These two sites also possess exceptional geomorphic values. The Three Sisters dune system is one of only two 'climbing confined parabolic' dune systems on the south New Zealand coast – the other being Sandhill Point (Hakapureirei). It is similar in character to the dunes of Stewart Island – in that it is a dune system transgressing a steep hinterland. The transgressive elements are of a parabolic dune nature (that is, one can recognise areas of deflation (erosion) and deposition with a parabolic geometry) but the ideal morphology is modified by the underlying morphology of the hinterland. Such dune systems typically comprise a range of environments associated with different rates of sand erosion and deposition and soil moisture conditions. Hence they also contain a range of habitats and a rich biodiversity. The Three Sisters dune system is the most accessible example of its type and retains moderate geomorphic function.

Fortrose Spit is the largest spit on the east coast of the South Island south of Lake Grassmere (and excluding Kaitorete Spit, which is not a true spit). The restoration work undertaken by DOC here has maintained the exceptional cushion plant communities, and provided for the restoration of foredune pingao. This work has also retained habitat for Lepidoptera, skinks and shorebirds. There are other long spits in New Zealand (e.g. Wairau, Farewell), but none afford the same restoration opportunities.

Non-native weed species pose the main threat to The Three Sisters and Fortrose sites. Marram grass and tree lupin are present at both sites. The current distribution of marram grass at Fortrose Spit is being maintained by ongoing management by DOC, but dominates dunes immediately adjacent to the restored area. A marram-dominated foredune has developed behind the beach at The Three Sisters site, which is largely preventing sand movement into the dune system. Continuing sand movement into this system is critical in maintaining active dune processes. Without management this site will stabilise with an associated loss of botanical and geomorphic values. Lupin at both sites is relatively sparse but appears to be actively invading. Other weed species (stonecrop, gorse *Senecio elegans*), browse by lagomorphs, and ATV vehicles pose additional threats at these sites.

Kawakaputa Bay is of geomorphic significance as an example of a composite barrier but retains few ecological values. Tiwai Beach retains populations of several threatened and at-risk dune plant species and the Awarua Barrier is of geomorphic significance as a sequence of prograded beach ridges. The remaining dune systems on the Southland coast retain few dunal values.

5.0 Discussion

5.1 Which dune systems continue to exhibit active dune processes?

Active dune processes are driven by wind and entail the erosion, transport and deposition of sand. Sand transport by wind gives rise to the diversity of landforms characteristic of dune systems; which in turn results in a mosaic of habitats, including wetlands, dune slacks, deflation surfaces, and active dunes. Thus the diversity of dune flora, including rare and representative species, is dependent on sand mobility.

Sand mobility is closely correlated to the absence of vegetation. As such the retention of active dune processes is able to be inferred from the density of vegetation cover — sparsely vegetated dunes are typically more mobile (or have the potential to be mobile). The presence of mobile dune landforms (for example, blowouts and moving parabolic dunes) is also indicative of active dune processes.

Site reports in the Beach and Dune Inventory and analysis of aerial photos indicates that the general trend over the past 20 years in the Murihiku District is towards increasing dune stability and decreased ecological integrity. The photographs show an ongoing decrease in the extent of bare and semi-vegetated sand in many dunes in the study area (Surat-Cannibal Bay, for example; Figure 7). Since fieldwork for the Inventory in the 1980s there has been an increase in the cover of non-native plants, particularly lupin, and loss of native dune species.

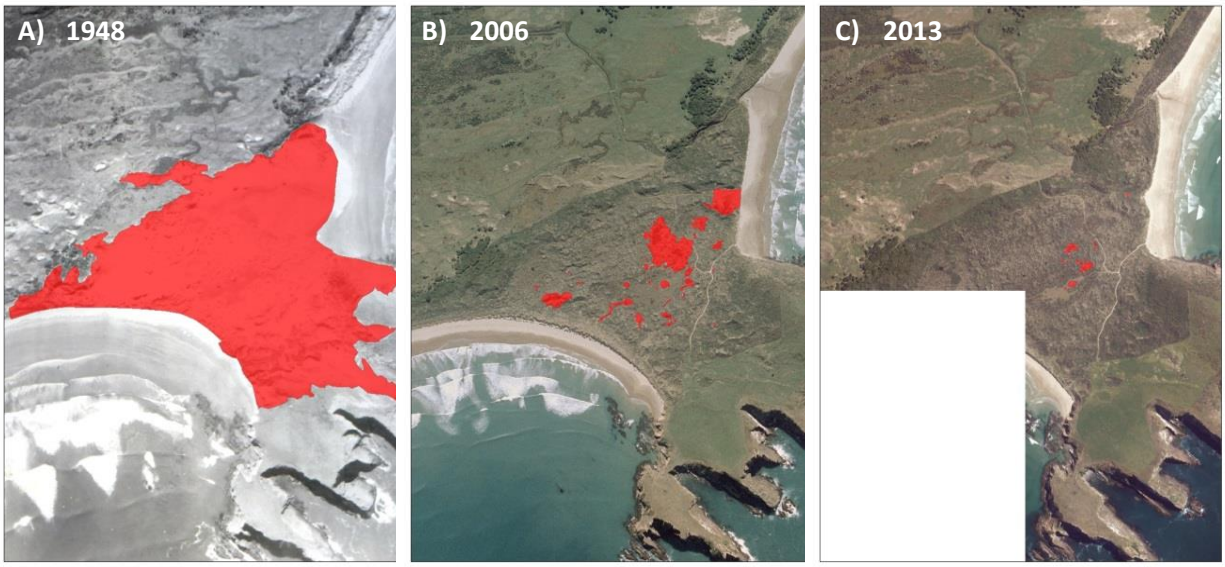

Figure 7. The decrease in extent of bare sand and sparsely-vegetated dune (red) at Surat-Cannibal Bay between 1948 and 2013. Much of the increase in vegetation cover is due to the invasion of the dune system by marram and tree lupin. Native dune plants are now largely restricted to those few remaining sandy patches identified in the centre of the 2013 photograph.

Few dunes within the Murihiku District now exhibit active dune processes. The dense vegetation cover associated with non-native plant species, particularly marram grass, has created stable dune surfaces with little wind-blown sand movement. Where active dune processes still occur these are typically restricted to the seaward margin (within 5-10 m of the beach) of the dune systems, manifest as minor blowouts, sand ramps, depositional lobes and recently deposited sand (Figure 8a). We observed these features on most beaches. More widespread active dune processes, typical of more natural dune conditions, were observed at Haldane Bay, Fortrose Spit and The Three Sisters dune systems (e.g, Figure 8b).

Sand movement continues at these three sites because non-native plant species do not yet dominate the inland portions of this dune system. Sand mobility occurs at Haldane Bay and Fortrose Spit due to recent dune destabilisation by grazing or DOC restoration programs, respectively, and is limited in spatial extent. The Three Sisters dune system is now the only dune system in the Murihiku District retaining widespread active dune processes and these can be expected to decline as marram invasion continues. Without active management the expansion of marram will continue to stabilise these dune systems, as has occurred elsewhere.

The potential to restore active dune processes within the Murihiku District is high. Many dune systems are comprised of landforms associated with past mobility (the now stable parabolic dunes at Surat-Cannibal Bay, for example). This indicates that climatic conditions in this region are conducive to re-establishing mobile dunes. Our experience in Stewart

Island and at Fortrose Spit suggests that such sand dunes can be effectively remobilised by removing marram.

Figure 8. A) Foredune at Helena Falls Beach showing a minor blowout (through which wind is funnelled and accelerated). Sand is transported off the beach, through this feature and deposited at the head of the blowout. These features can develop into parabolic dunes if the strength and frequency of wind events exceeds the colonising abilities of the dune vegetation. B) Active dune processes are evident at Fortrose Spit as a result of ongoing DOC restoration activities. Evidence of these processes includes large areas of bare or sparsely vegetated sand, mobile dune landforms including sand sheets, slip faces and parabolic dunes that are actively migrating over existing landforms, and the vigour of those plant species (e.g. pingao, marram grass) characterised by increased growth following burial by sand.

5.2 Which dune systems should be prioritised for restoration management, based on existing ecological integrity?

The potential to restore the sand dunes of the Murihiku District is high. Many dunes are large and able to support a diversity of dune habitats. The non-native weed plant species lupin and marram pose the main threat to most systems, and successful restoration programmes targeting these species in dune systems have occurred elsewhere in New Zealand (e.g. Kaitorete Spit, Mason Bay, Fortrose Spit). Finally, many dunes within the Murihiku District are administered by DOC. The main constraint to successful restoration will be the time and cost.

Table 1 ranks the sand dunes of the Murihiku District as priorities for restoration management. Several dunes in the Catlins district were geomophically and ecologically similar, and have experienced similar levels of modification (the prograded barriers of Tahakopa, Tautuku and Waipapa, for example). This made it difficult to distinguish these systems — restoration could occur at any one of these sites with good conservation outcomes. Further, the loss of dunal values within the Catlins district has been rapid and remains ongoing. Only a few dune systems retain native dune species for example. Prompt action is required at multiple sites to safeguard these values.

Overall we consider the Tahakopa Beach dune system to be the highest priority for restoration in the Catlins district with Tautuku a close second. These dune systems retain diversity of native dune species and dune habitats, are backed by native forest, and are representative of the prograded barrier systems of the north-east Catlins coast. Tree lupin and marram have modified the geomorphology and ecology of these systems, however, these effects are not irreversible. We rank Tahakopa slightly higher than the nearby and very similar dune system at Tautuku because of the presence of pīngao, because of the popularity of this site with the public, and because the wider landscape is administered by DOC. Further, the values that remain at Tahakopa are highly threatened whereas those at Tautuku are less so in the short to medium-term. Ideally both would be managed for conservation purposes.

Waipapa Beach is also ranked highly. This site retains a high diversity of native dune species and dune habitats, and the dune slack environment is likely to be regionally significant. We consider Waipapa Beach to be a slightly lower priority for restoration than Tahakopa and Tautuku because of its size and lack of clear landform boundaries which would make restoration difficult. In addition, many of the values at this site could be protected by controlling key weed species around selected populations of significant species, whereas those values present at Tahakopa and Tautuku require more substantial and urgent management.

Table 1. Ranking of sand dunes in the Murihiku District for restoration management

Site	Ranking
Catlins Dunes	
Tahakopa Beach	High
Tautuku Bay	Medium high
Waipapa Beach	Medium high
Waipati Beach	Medium
Long -Dummies Beach	Medium
Surat-Cannibal Bay	Medium low
Puarakaunui Bay	Low
Waipapa Point	Low
Haldane Bay	Low
Porpoise Bay	Low
Clutha River Mouth	Low
Jacks Bay	Low
Willsher Bay	Low
Southland Dunes	
Fortrose Spit	High
The Three Sisters	High
Tiwai Beach	Medium
Oreti Beach	Low
Colac Bay	Low
Kawakaputa Bay	Low
Te Waewae Bay	Low

We consider Long-Dummies Beach and Waipati Beach to be lower priority sites for restoration within the Catlins district. Waipati is similar to Tahakopa Beach and Tautuku Bay, but difficulties with land tenure, access to the site, and a relative lack of landform complexity rank this site lower. The Long-Dummies beaches are small, contain relatively simple dune forms, and have limited geomorphic complexity. It does retain significant populations of native dune plants, particularly *Euphorbia glauca*, and a small population of pīngao. We do not recommend the widespread restoration of this site ahead of other priorities within the Catlins district; however, actions should be taken to protect these species. This could entail limited weed control work and management of grazing.

We do not consider Surat-Cannibal Bay a restoration priority, despite retaining a diversity of dune landforms, some native dune plant species, and despite its popularity with tourists. The large size and degree of modification of this site, and the limited number of native dune plant species, means that considerable time and money would need to be invested to restore this site. There are other sites in the Catlins district where this time and money

could be spent for better conservation outcomes. However, targeted actions to protect those small populations of dune plants remaining could be considered. Additionally, the eradication of gorse and pine from the dunes at this site could at present be achieved relatively easily since they currently occupy a small area. These species are invasive in coastal dunes in Southern New Zealand and will spread if management does not occur.

All other dune systems in the Catlins district are severely modified by weed invasion and/or farming activities, and retain few ecological values. These effects could eventually be reversed at considerable expense, however, better conservation outcomes would be delivered with less investment of time or money at the dune systems identified above.

Within the Southland region we consider Fortrose Spit and the Three Sisters to be high and equal priorities for restoration. Fortrose Spit has exceptional ecological values and restoration work at this site is already well underway. The Three Sisters also retains exceptional ecological and geomorphic values which will be lost unless action is taken. The Three Sisters is also an intact example of the hill-climbing transgressive dunes of the Southland coast. While similar dunes are present on the west coast of Stewart Island, the Three Sisters is the last remaining exemplar on the mainland coast. All others dunes of this type have been substantially modified by weed invasion or farming.

Management actions to protect significant populations of native dune plants at Tiwai Beach, namely weed control, could be considered. All other dunes in the Southland District are highly modified by weeds and farming activities and have low ecological values.

5.3 What are the most appropriate management options for priority restoration sites?

Dune restoration in the Murihiku District will largely comprise weed control. It may also be necessary to reintroduce native plant species where native species have been displaced. At all sites we recommend that regular and systematic monitoring be implemented to measure the effectiveness of the operations in removing target weed species, as well as the recovery of desired ecological and geomorphic properties. Management plans that clearly identify restoration goals and the proposed sequence of actions required to achieve these should be produced for each site.

Regular technical meetings, similar to the DRAG (Dune Restoration Advisory Group) meetings related to the Stewart Island dune restoration program should be held. These should occur on a biannual or annual basis, and involve all interested personnel (field rangers, managers, technical support, independent experts (university)). These meetings might be held prior to the summer field-work season. The results of the restoration work during the previous season would be discussed; new opportunities and/or challenges

identified; and the up-coming seasons work planned. Such meetings have been critical elements in the success of the dune restoration projects on Stewart Island, particularly in times of financial and institutional uncertainty. They install a sense of purpose and continuity that is often otherwise lost and facilitate relevant research.

Marram, lupin, and gorse can be controlled though the application of herbicides. Any management actions will need to be ongoing. Marram re-grows profusely from buried rhizomes following the initial application of herbicide and such regrowth might occur for some years. Managers should plan for at least three annual broad-scale applications of herbicide followed by targeted ground-based spraying for a further 4 years before re-growth will cease. Ongoing biennial sweeps (systematic, grid searches) of the dunes will be required to prevent a second phase of regrowth from the buried seed bank and identify new infestations developed from marine-dispersed rhizomes.

Lupin and gorse also form persistent and large seedbanks. The naturally sparsely vegetated character of New Zealand active sand dunes means that the regeneration of these species from the seed bank cannot be controlled through the replanting of native shrubs and the establishment of a dense native plant canopy. Regular and ongoing actions to remove seedlings before they mature will be essential to the success of restoration programmes.

We wish to state that although a dune system may not be a high priority for restoration, it does not mean that management activities could not be undertaken to protect particular values. For example, weed control could be undertaken where lupin or gorse is not yet dominant, to prevent the spread of these species, or weed control could target remnant populations of native dune species to protect these species in the short-term.

Finally, even if no restoration works occurs at a site, ongoing monitoring of the spread of key weed species and/or the decline of conservation values (native dune species, habitat diversity, etc) should be considered. The ecological integrity of sand dunes in the Murihiku District has declined considerably since the 1980s. Ongoing monitoring to identify current trends will allow management to occur in a timely fashion if this decline continues.

Specific restoration actions are outlined for each priority dune system. For each site we identify the actions required to protect existing values and, secondly, achieve geomorphic and ecological restoration of the site.

Tahakopa Beach

Small but significant populations of native dune plant species remain at the eastern end of the bay. Manual control and/or the selective application of herbicide to remove lupin and marram around individual plants is required to conserve pīngao at this site, over the short to

medium term. Other native dune plant species are restricted to a few, relatively sandy patches where lupin is absent and marram is sparse. Conservation of these species will depend largely on preventing lupin from forming a dense canopy in the vicinity of these species.

The removal of marram, lupin and gorse is required to restore the Tahakopa dune system. We observed few other weed species in the dunes here. Gorse is restricted to a small section at the eastern end of the bay and should be eradicated to prevent further spread. Lupin and marram are widespread. We recommend that control of these species be initiated at the eastern end of the bay where some native dune species remain and the dune system retains the greatest landform diversity. Control should be progressively expanded to encompass the entire bay.

Scattered pīngao is present at the eastern end of the bay and it is likely that more will be revealed once marram and lupin are removed. Nonetheless, the planting of pīngao and other selected native dune plants to expand the range of these species might be beneficial. Reintroducing native species would 1) increase the spatial distribution of native species, which would reduce the vulnerability of these species to episodic disturbance; and 2) the widespread colonisation of the dunes by native dune plants will result in more natural dune forms and associated dune morphology. There would be no harm dividing some of the current survivors and planting in better locations. Protection of these plants from lagomorph and deer browse may be needed.

Tautuku Bay

Tautuku Bay retains extensive populations of several native dune plant species. These are restricted to the southern half of the bay in areas where lupin has not yet formed a dense canopy. The conservation of these species at this site will depend on preventing the further spread of lupin. We recommend that control of lupin to zero density be considered south of the Lake Wilkie access track.

Gorse is currently present, though there are only a few plants. Regardless of any wider restoration works we recommend that gorse is eradicated from Tautuku Bay. Control of Scotch thistle should also be considered as this species is present currently in low densities. The populations we observed are mapped in Appendix 2.

We recommend that any wider restoration works be focussed initially at the southern end of the bay where the barrier widens and where a range of native dune plant species are present (as identified in Appendix 2). Work should be progressively expanded to the northeast to encompass the whole bay.

Restoration will entail the removal of marram to restore the geomorphic dynamism of this site. The increased sand mobility that will follow will have the added advantage of decreasing habitat for lupin and other weed species that require stable dune surfaces, such as *Hieracium* spp. Additional weed control work targeting lupin will be required. Pīngao would need to be reintroduced and protected from lagomorph browse.

Waipapa Beach

We recommend that restoration works be focussed along the eastern half of the beach within the DOC reserves as this is where most of the values are retained. The outlet of Lake Brunton forms a natural boundary for restoration. As at Tahakopa and Tautuku management could be initially focussed on preventing the spread of lupin and gorse into areas which retain significant populations of native dune plant species and targeted weed control to conserve the remaining pīngao. Subsequent management could involve the removal of marram and reintroduction of pīngao. Vehicles and probably lagomorph browse will need to be managed.

A single plant of *Gunnera tinctora* has been reported to be growing in the foredune (Rance 2006), but was not observed during this study. This species is highly invasive and needs to be eradicated (if still present) at Waipapa Beach.

The Three Sisters

The removal of marram, lupin and gorse is required to restore this system. Lupin and gorse are widespread, but not yet dominant. These species appear to be actively invading and pose the most immediate threat to the significant values of this site. We recommend a program to control gorse and lupin to zero-density, because of the persistent effects associated with the invasion of these species in coastal dunes. *Hieracium* spp. is also present, but this species poses less of an immediate threat. The spread and impact of *Hieracium* spp. at The Three Sisters should be monitored but no immediate control works are required.

The removal of marram is critical in order to re-establish sand transfer from the beach to the inland dune system, and hence protect the values of The Three Sisters dune site which are dependent on a degree of sand mobility. We recommend that marram be controlled to zero density through the application of grass-specific herbicides in a manner similar to the dune restoration program currently employed on Stewart Island. Ground-based methods of delivering herbicide can be used where marram is patchy and sparse, the inland dune areas for example. Where marram is dense, primarily in the foredune environment, aerial applications of herbicide will be required. Removing marram will eventually decrease the stability of this dune system limiting the spread of these species; however, suitable habitat

will remain for lupin and gorse even under increased conditions of sand mobility. Additional control targeting these species will be required.

The strategy employed to control marram will depend on the availability of funding. It is likely that funding will be insufficient to treat marram throughout the site from the outset of operations. We recommend that marram control be focussed initially on the dune at the centre of the bay between the two streams, as this is where most of the dunal values threated by marram invasion remain. Management should progressively expand to encompass the entire bay.

Fortrose Spit

We agree with the recommendations of Bythell and Rance (2014) for the restoration of Fortrose Spit. These are:

- that the dune restoration/marram control work continues. Marram control has maintained and enhanced the pīngao dominated dunes and *Raoulia* mat/daisy herbfields. Control of the remaining gorse will benefit the special plant communities on the Spit.
- that the dune restoration and marram control be expanded to progressively include the whole of the Spit.
- control of other weeds, particularly gorse and other woody weeds should be maintained.
- lagomorph control should continue to ensure these pests do not get beyond acceptable levels (i.e. levels which minimise any ecological impacts to important ecosystems and threatened species) levels on the Spit.
- proposed translocation work of native dune plants should continue. Translocation techniques may require modification in order to achieve success with certain species (e.g. *Gunnera hamiltonii* and *E. glauca*).
- investigate methods of controlling stonecrop. This species is the greatest threat to the highly significant *Raoulia* mat/daisy herbfields.
- to establish monitoring of the dune vegetation.
- to establish monitoring of the key threatened plant populations, notably pīngao, *Raoulia aff. hookerii*, *Ranunculus recens*, *P. lyallii*, *Myosotis pygmea* and *Geranium sessiliflorum var. arenarium*.
- advocacy work is necessary in order to promote the values of the Spit to the local community. In particular it is important to get the ATV and trail bike users appreciate the values here as they are responsible for much of the damage occurring to threatened plants.
- promoting the site to visitors from outside Southland may also be worthwhile. This advocacy work could be 'piggy-backed' with promotional material for Waituna.

- the production of a pamphlet or small booklet outlining the values of Fortrose Spit would go a long way in encouraging people to protect and value the area.

The current restoration works undertaken by DOC have been successful in protecting and enhancing the values of the Spit. Without ongoing weed control the target species (marram, gorse, and other woody weeds) will reinvade. Small populations of these species remain within the restoration area. We propose that an exclusion line be drawn around the area where restoration works have occurred and the target species within controlled to zero-density (Appendix 2).

We agree that given the success of the existing restoration works at Fortrose that the programme should be expanded progressively to include the whole of the Spit. However, we feel that this expansion should not occur at the expense of restoring The Three Sisters dunes, if funding is limiting.

Lagomorph control is periodically undertaken in accordance with Regional Pest Management Strategy responsibilities (Bythell and Rance 2014). Monitoring should be implemented to identify the impact and therefore 'acceptable' level of lagomorph density. This study would benefit dune conservation elsewhere in New Zealand as currently the impact of lagamorphs on dune vegetation is poorly understood. Similarly, methods to control stonecrop should be investigated. Finally, regular and systematic monitoring of both native dune vegetation and the weed control programmes should be implemented.

If not already prepared a management plan for the restoration program should be written which outlines a proposed sequence of actions at the spit, and identifies restoration goals for the future. Regular meetings, similar to the DRAG (Dune Restoration Advisory Group) meetings related to the Stewart Island dunes should be held.

5.4 Is it practical to improve New Zealand sea lion habitat at Cannibal Bay and Surat Bay; in particular is it realistic to modify foredune morphology to improve habitat for pupping and female haul-out?

The New Zealand sea lion is endemic to New Zealand and is listed as 'threatened' and 'nationally critical'. New Zealand sea lions once bred throughout New Zealand, but were extirpated from mainland New Zealand by the 1800s (Roe *et al.* 2014). A small number of female sea lions have bred on the Otago Coast since the 1990s (Auge 2011). Given the decline in sub-Antarctic sea lion populations in recent years, facilitating the recovery of this species on mainland New Zealand should be a priority conservation measure (Roe *et al.* 2014, J. Fyfe pers. comm.). To this end a Threat Management Plan for New Zealand sea lions is currently being developed by DOC and the Ministry for Primary Industries.

Breeding female sea lions spend a significant period of time on land — pups are nursed for 12 months during which females alternate foraging trips at sea with nursing periods on land (Augé 2006, Augé 2011). This suggests that the availability of suitable habitat for pupping and nursing may, in part, determine the re-establishment of this species on mainland New Zealand.

The preferred habitat of female sea lions during the pupping and nursing periods in the sub-Antarctic Islands comprises coastal forest or scrub, located behind a long flat fine-sand beach and low dunes (Augé 2006). Female sea lions on the mainland New Zealand coast have different habitat needs to sea lions at sub-Antarctic breeding sites, however, the preference on the Otago Coast seems also to be for sandy beaches and forested or scrub-covered inland areas which provide protection against adverse weather and male sea lions. Male sea lions will also move inland, although over smaller distances, mostly to avoid adverse weather.

The current beach and dune conditions at Surat-Cannibal Bay contain all the essential habitat attributes required by female sea lions for pupping and the subsequent nurse period (flat sandy beach, forested/scrub inland areas, duneland); however, modification of dune systems by marram grass has reduced the habitat suitability of this site.

Foredune progradation (building seawards) and accretion (building vertically) in association with marram grass has resulted in both a reduction in beach width and associated beach habitat for sea lions and restricted access to the inland dunes due to the increased height of dune and foredune scarps. Under typical conditions (i.e., not extreme storm surge) only a small amount of the contemporary beach remains at high tide compared to the relatively wide beaches evident in the 1948 photographs. Coastal erosion has occurred more frequently as the coastline has prograded, resulting in the formation of high dune scarps along stretches of the bay. Sea lion access into the dunes is now restricted to a few areas where the dunes are low or where sand ramps have formed in front of small breaks in the scarps. We observed sea lion tracks along the base of the dune scarp for some distance to one of these ramps (Figure 9). Clearly sea lions now have to travel long distances at times to access the dunes.

Restrictions in dune access pose challenges when considering breeding female sea lions. At the sub-Antarctic breeding sites, female sea lions form harems during the pupping period. Females are protected by a dominant male from disturbance and harassment by other male sea lions (Campagna *et al.* 1992). On mainland New Zealand, however, breeding is solitary. Females hide from males to pup (J. Fyfe pers. comm.). The available habitat for females is reduced where coastal erosion has limited dune access. Further, the restriction of dune access to a few discrete points (as described at Surat Bay) may make it easier for males to ambush females. This ambushing of female sea lions is not currently an issue, but could

Figure 9. Sea lion tracks along the base of the scarped foredune at Surat Bay, June 2015.

potentially become a problem if the male sea lion populations increase. It is expected harems will form on the mainland once the female population reaches a 'critical mass', but it is not known what size the population of breeding females will need to be for this to occur.

To improve sea lion access at Surat-Cannibal Bay, sea lion access points could be created through the mechanical excavation of the existing dune where the foredune (the most seaward dune) is low (less than 2-3m). These conditions are currently found along much of Surat Bay except for the eastern third of the bay, and the southern half of Cannibal Bay. Excavation of this type may not be immediately necessary, however, since sea lions can currently access the Surat-Cannibal Bay dunes at a several points.

Mechanical excavation could take one of two forms. Small notches could be cut with an excavator at intervals along the foredune to establish new access points. Wind acceleration through these notches might keep them open for a time, but they would need periodic maintenance. This method would provide a quick and relatively inexpensive way to increase sea lion access, but might require annual works. Wider notches would be more persistent and require less maintenance than. Multiple access points would need to be created to minimise the ambushing of female sea lions by males.

Alternatively, sections of the foredune could be excavated and re-shaped to form a foredune inland of the current dune with gently sloping seaward slopes, similar to those actions undertaken to increase the hazard protection role of foredunes on metropolitan

coasts (e.g. Clifford Beach, Christchurch). The new foredune would need to be re-vegetated with dune-binding vegetation following re-contouring. Native dune plants, particularly pīngao, should preferably be used. Alternatively marram could be allowed to re-establish.

This approach has several advantages. Reforming the foredune inland of the current dune reduces the frequency of erosion events, the gentle gradient of the seaward face of the foredune would mean that only low scarps are formed when erosion of the foredune did occur, and re-contoured dunes tend to be resilient to future erosion events, recover well and maintain their shape. Incorporating the planting of pīngao and other native dune plants allows for ecological goals to be met as well improving sea lion access. Rather than dictating where sea lions are to access the dunes re-contouring of dunes along substantial lengths of coastline would allow the animals to select access points that best suit their needs. Reshaping the foredune would, however, be expensive if pīngao were to be planted, but significantly cheaper if marram was allowed to re-establish from rhizome fragments. Even a small length of coast would cost in the order of $10,000s to reshape and plant with pīngao (Hesp and Hilton 2013). Sustained annual works would also be essential to prevent marram reinvasion and ensure the success of the works.

Given the costs associated with reshaping and replanting the foredune, we recommend that notches in the foredune be cut if urgent action to improve sea lion access to the Surat-Cannibal Bay dunes is considered necessary. It is difficult to recommend costly and long-term reshaping works given uncertain and limited funding and the other restoration priorities in the Catlins district. However, if reshaping does occur then we recommend that it is implemented at the New Haven end of Surat Bay (Appendix 2), where remnant podacarp forest provides potential nurse sites for female sea lions. The popularity of this portion of the bay with tourists means there is the potential to develop a sand dune/sea lion advocacy site through the replanting of native dune plants, and potentially to involve the community here.

Sea lion access points could be established elsewhere in Surat-Cannibal Bay; however, the dunes are higher and would require more substantial and more costly excavation. Dunes could be mechanically excavated to create channels similar to those at Sandfly Bay on the Otago Peninsula. Alternatively, a program focused on the control of marram grass would eventually result in the landward retreat of the foredunes and the formation of dune morphologies more likely to provide for sea lion access. However, this course of action would have to be part of a sustained dune restoration project and as discussed earlier we feel other sites in the Murihiku District are currently higher priorities for restoration.

5.5 Are there other sites in the Catlins district that could be considered for New Zealand sea lion conservation — primarily sites for pupping and female haul-out?

Habitat for sea lion pupping and haul-outs within the Catlins district is not currently limiting. The main limit on sea lion use of a beach is restricted dune access caused by a combination of marram grass dune development and episodic coastal erosion. Most foredunes along the Catlins coastline show evidence of erosion, which in some cases (e.g. Tahakopa) appears to be persistent. However, most retain some areas where sea lions can access the inland dune areas. Sea lions readily move with pups to more suitable habitat if required. Until sea lion numbers increase in mainland New Zealand it is difficult to recommend that widespread modification of dunes to enhance access occurs.

The restoration actions outlined in section 6.3, while focussed on the ecological and geomorphic restoration of selected Catlins dunes, are not inconsistent with sea lion conservation. The removal of marram and/or lupin will decrease the shelter available for sea lions at some sites; however, it will also facilitate increased access to the inland coastal forest.

6.0 Conclusion

The sand dunes of the Murihiku District are nationally significant. They are physically distinctive because, in the main, sand transport and dune system development is oriented alongshore within embayments. They display a remarkable diversity of landscapes and dune forms, more so than any other region in New Zealand. Dune forms include prograded foredune barriers (Tahakopa, Tautuku and Waipati); large sand spits (Fortrose and Porpoise Bay); and hill-climbing transgressive dune systems (The Three Sisters, Haldane Bay). In contrast to sand dunes elsewhere in New Zealand, the dune systems of the Murihiku District have experienced low levels of afforestation and urbanisation. Further, many adjoin relatively unmodified forest and/or estuaries and lagoons, forming now rare vegetation sequences.

Non-native plant species, particularly, Marram and lupin have modified the geomorphology and ecology of all sand dunes in the Murihiku District to some degree, with an associated loss of ecologic and geomorphic values. This decline in value has been rapid and remains ongoing. Prompt action to halt this loss is required. Other threats include grazing, browse, and vehicle damage.

The potential to restore several dune systems is high. This will involve, in the main, removing marram and lupin, with the potential to replant with natives. The restoration actions that have been attempted at Fortrose Spit appear to have been very successful, albeit a question remains around the impact of lagomorphs at the Spit. However, one of the

best dune systems in the Murihiku District, The Three Sisters, has received limited restoration to date. Finally, there is the potential to achieve something quite special in the Catlins where sand dunes adjoin podacarp forest.

Sand dunes in the Catlins district provide good habitat for sea lions, albeit coastal erosion currently limits access to inland dune areas along significant lengths of coast. Dune forms could be modified at selected sites to improve access. Overall, however, habitat is unlikely to be limiting given the low numbers of sea-lions on the mainland New Zealand coast. It is important to recognise, however, that limited dune access may become an issue in the future as the sea lion population increases and if the current period of coastal erosion is sustained. Implementation of an adaptive management plan to determine the implications of restricted dune access on breeding females so that any adverse effects were mitigated in a timely fashion could be considered.

Any restoration actions that are implemented need to be adequately monitored and we highly recommend that regular technical meetings between all involved parties be held to ensure the restoration programmes are supported by the best possible technical advice. Finally, we suggest that this report is followed by a meeting with the authors of the report to discuss the recommendations. Site visits to selected dune systems at this time would be beneficial.

7.0 Acknowledgements

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Appendix 1: Site evaluations

Site: Willsher Bay

Location: -46.38°Lat, 169.78°Long

Inventory Rating: 3

Description:
Narrow foredunes south of Kaka Point township. Dunes are densely vegetated and dominated by marram and lupin. Recent erosion has formed dune scarp approximately 1.5m high.

Values:
No significant ecological or geomorphic values. The foredune here is important for coastal hazard mitigation.

Threats:
Plant communities are dominated by marram. Tree lupin is present.

Potential for restoration:
Low priority for restoration due to the absence of any significant dunal values. A lack of isolation from humans means that other sites in the Catlins region are higher priorities when considering the restoration of sea lion habitat.

Site: Surat-Cannibal Bay

Location: -46.47°Lat, 169.74°Long

Inventory Rating: 10

Description:

The dunes evaluated at Surat-Cannibal Bay are located within the areas administered by DOC (Surat Bay Scenic Reserve, False Islet Recreation Reserve, and Surat Bay Conservation Area and Cannibal Bay Marginal Strip). These areas retain the most significant landform and ecological values, and were considered to have the greatest potential for restoration. Dune landforms extend for some distance outside DOC lands, but are modified and degraded through agricultural land use.

Cannibal and Surat Bays are part of the same dune system, connected by a tombolo that joins False Islet to the mainland. Dune landforms contain a significant transgressive element with parabolic dunes, precipitation ridges, deflation surfaces and dune slacks. Aerial photography show these dunes as highly mobile with little vegetation cover in 1948, but are now densely vegetated and largely stable. The transgressive dune forms are oriented largely along a south-west/north-east axis suggesting that the south-west winds drive dune mobility. Some dune forms, particularly along the Cannibal Bay coast, are oriented to the north-east/south-west indicating that the north-east wind may also be significant, albeit relatively less so.

In general the dunes are high, between 5 and 20m. The foredune along both bays had been recently eroded forming a steep dune scarp 1-6m high.

Values:

Both bays are important haul-out and probable breeding sites for New Zealand sea lions, particularly the southern end of Cannibal Bay and the eastern end of Surat. Elephant seals also haul-out on these beaches. The site contains a diversity of dune habitats (including stable, previously mobile, dune forms, deflation surfaces, dune slacks). The geomorphology and ecology of these have been modified by invasive plants. We observed native dune plants in a few small, relatively sandy, areas

where lupin is absent and marram is sparse. Species recorded include; *Pimelea lyallii*, *Coprosma acerosa, Geranium sessiliflorum var. arenarium*, *Raoulia sp. aff. hookeri*, among others. *Ficinia spiralis* (pīngao) was recorded in 1977 (Johnson 1992), but was not observed during the survey for this report. A dune slack at False Islet contains several threatened and at risk plant species including *Euchiton polylepis* , *Lobelia arenaria* , and *Acaena pallida* (B. Rance pers comm).Scattered patches of remnant Totara forest are present on the inland, older parts, of the dune system.

Threats:

Plant communities are dominated by marram and lupin. Other notable dune weed species, particularly *Pinus radiata* and *Hieracium* spp. are present. No lagomorph sign was observed, but rabbit browse has been noted as a problem in the past (Johnson 1992). Vehicle tracks, probably motorbikes, were observed on the dune slack surface at the centre of the bay. The False Islet dune slack site appears to be slowly drying out and is suffering from exotic plant invasion/competition (B. Rance pers comm).

Potential for restoration:

The size and the diversity of habitats at this site, coupled with the significance of this site for wildlife, make this site an attractive location for restoration. Restoration would require the removal of lupin and marram, and the reintroduction and/or assisted spread of native dune plants. The existing, albeit small populations, of several native dune plant species could provide a seed source. Regardless of any restoration activities at this site, these species should be conserved. Given the extent to which this dune system has been invaded by non-native plants, however, by lupin in particular, other sites in the southland region are likely to be higher priorities for geomorphic and ecological restoration.

The potential to restore sea lion habitat at Surat/Cannibal Bay is covered in Section 6.4. In brief, scarping of the dunes by wave action appears to be limiting sea lion access. Actions to provide for sea lion habitat could be undertaken, such as the mechanical re-contouring of foredune forms, that would not be inconsistent with the goals of geomorphic or ecological restoration.

Site: Jacks Bay

Location: - -46.49 °Lat, 169.70 °Long

Inventory Rating: 4

Photo: M. Moore, 2015

Description:

Dunes occupy a 10-40m wide strip seaward of houses and road. Landforms comprise prograded foredunes up to 3m high.

Values:

Few ecological values or geomorphic values. Sea lions haul-out on the beach, but the height and steepness of the dunes probably limits access further inland.

Threats:

Plant communities are dominated by marram. Tree lupin is present.

Potential for restoration:

Low priority for restoration due to the absence of any significant dunal values. A lack of isolation from humans means that other sites in the Catlins region are higher priorities when considering the restoration of sea lion habitat.

Site: Purakaunui Bay

Location: -46.5°Lat, 169.6°Long

Inventory Rating: 4

Description:
Small prograded barrier comprised of relict foredunes or beach ridges now modified by grazing and dominated by pasture grasses. Low dunes formed by marram occupy a narrow zone along the seaward margin of the barrier. Administered by DOC (Purakaunui Bay Scenic Reserve).

Values:
Haul-out site for New Zealand sea lions. Numerous tracks and sea lion sign was observed within the low marram dominated dune along the seaward portion of the barrier, with little sign further inland. No native dune plants were observed.

Threats:
There are few direct threats. The site is modified by past farming activities and retains few botanical values. Lupin was absent from this site and steps should be taken to prevent its invasion.

Potential for restoration:
Eradication of marram from this site would be relatively easy given its small size and limited geomorphic complexity. The site provides a nice 'unit' for restoration given the separation of the barrier from the road and campground by the river. However, given the absence of indigenous dune plant species, significant reintroduction and investment in planting would be required. Other sites within the Murihiku District will be higher priorities for restoration. Further, marram is currently providing good habitat for sea lions.

Site: Helena Falls Beach (Long Point/Irahuka Reserve)

Location: -46.56°Lat, 169.57°Long

Inventory Rating: 6

Description:

Small dune system between prominent headlands. Administered by DOC (Helena Falls Scenic Reserve) and the Yellow-eyed Penguin Trust.

Dune forms are transgressive in nature, comprised primarily of high parabolic dunes. The foredune contains blowouts and sand ramps, and there is evidence of frequent sand transport through these features. Marram forms a dense vegetation cover landward of the foredune and the dunes here are now stable.

Small beaches in bays either side of Helena Falls Beach between Long Point and Pillans Head contain small dunes (Johnson 1992). Based on aerial photographs these are dominated by marram or pasture, and are unlikely to have significant ecological or geomorphic values.

Values:

Carex pumila grows near the stream but no other native dune plants were observed. The involvement of the Yellow-eyed Penguin Trust suggests that this site provides habitat for this species. This site probably provides good haul-out habitat for sea lions. Blowouts and sand ramps, as well as the stream at the east of the bay allow sea lions to access inland areas of the dune system. The marram here would provide good shelter.

Threats:

Grazed by cattle and sheep. Marram probably occupies 100% of the available habitat at this site. Lupin was absent and steps should be taken to prevent its invasion. We observed a wild cat in the dunes when we visited this site.

Potential for restoration:
The potential to reinstate active dune processes at this site is high. Eradication of marram from this site would be relatively easy given its small size. Given the absence of indigenous dune plant species, significant reintroduction and investment in planting would be required. Further, marram probably provides good habitat for sea lions. Other sites in the Catlins region are likely to be higher priorities for restoration. Revegetation of the inland dune areas with shrubs may increase the habitat potential of this site for wildlife.

Site: Tahakopa Bay

Location: -46.56°Lat, 169.49°Long

Inventory Rating: 18

Description:

Large prograded foredune barrier between relic sea-cliffs to east and Tahakopa River to west. Administered by DOC (Tahakopa Bay Scenic Reserve).

Landforms comprise a sequence of high (4-10m) foredunes seaward of a lower foredune and/or beach ridges—all vegetated with coastal forest. There is a narrow margin of recently active (early 20th century) sand dunes on the seaward margin, now largely stabilised by marram.

Values:

Tahakopa Bay, Tautuku, and Waipati Beach contain a now rare sequence of plant communities from mobile sand dune (albeit now dominated by non-native plants) through to late successional stage coastal forest. We observed several threated and at risk native dune plant species at the eastern end of the bay in a few small sandy areas where lupin is absent and marram is sparse (as depicted in the above photo), including *P. lyallii*, *C. acerosa, G. sessiliflorum var. arenarium*. Scattered moribund plants of pīngao, overgrown with lupin and marram, were also observed in the eastern portion of the bay. Native dune species appeared absent from the western end of the bay.

Threats:

Invasion by weeds pose the main threat to this site. Marram is widespread and occupies close to 100% of available habitat. Lupin is abundant and native dune plants were recorded only in the few areas that remain free of lupin. Gorse is present at the eastern end of the bay and appears to be spreading west.

M. Hilton recorded several large patches of pīngao in 1999. In 2010 he observed that lupin had

invaded all areas of pīngao and that they were at risk of being displaced. We found only a few relatively moribund scattered plants of pīngao in 2015.

Observations made by the authors over the past 15 years indicate the trend at Tahakopa Bay is one of shoreline retreat. A high steep scarp formed by wave erosion was present along the length of the bay when visited in July. Old soils were exposed and large trees had been eroded by waves, particularly at the western end of the bay. While this erosion is likely the consequence of natural coastal process, it has the reduced the amount of sand dune habitat in several places.

Deer sign is common in the dunes and browse of native dune plants is possible.

Potential for restoration:

The potential to recreate a sequence from active dune through to forest dominated with native plant communities, administration of this site by DOC, the formation of clear management units by the definition of the dune system by the Tahakopa River and headlands, and the retention of several native dune plant species increases the restoration ranking of this site. In addition, pīngao has only recently been displaced from this site and it is possible that a seed bank remains. Lupin, however, dominates the site and has proved to be difficult to eradicate due to a persistent seedbank elsewhere. Gorse will pose a similar problem at the eastern end of the bay.

Any further shoreline retreat will continue to reduce dune habitat. There is some risk that large amounts of time and money could be invested in the Tahakopa dune system only to lose the restored dunes following coastal erosion. However, most of the remaining botanical values are found at the eastern end of the bay where recent rates of shoreline retreat have been low compared to the western end of the bay. Further, increased aeolian sand transport inland is likely to follow the removal of marram, increasing the available sand dune habitat.

Site: Tautuku Bay

Location: -46.58°Lat, 169.43°Long

Inventory Rating: 18

Description:

A prograded foredune barrier located between relic sea-cliffs to the north and Tautuku River to south.

Landforms comprise a sequence of high foredunes vegetated with coastal forest. At the north end of the bay there is a narrow margin of recently (early 20th century) active sand dunes on the seaward margin, now stabilised with marram and lupin. Recent coastal progradation has formed a narrow, low incipient foredune (1-2m high) seaward of a high (8-10m) established foredune south of the Lake Wilkie access track. The incipient foredune increases in width along the bay to the south, culminating in 110m wide zone comprised of 3 foredune ridges and minor transgressive dune forms.

At the southern end of the bay a spit approximately 150m wide and 400m long encloses the mouth of the Tautuku river estuary. This spit has largely formed since 1948, although midden at proximal end of the spit indicate that parts of the spit must have been present for some time. Landforms comprise a foredune ridge enclosing a zone of hummocky dunes, deflation surfaces, relatively dry dune slacks and relict washover features.

Values:

Tautuku Bay contains a now rare sequence of plant communities associated with active sand dunes (albeit now dominated by non-native plants) through to late successional stage podocarp coastal forest. The incipient foredune and spit south of the Lake Wilkie access track are dominated by marram, but retain large populations of threatened and at risk native dune species; in particular *P. lyalli*, *C. acerosa*, *G. sessliflorum var. arenarium*. The southern end of the bay contains a diversity of dune habitats (now stable active dune forms, deflation surfaces, dune slacks), albeit the geomorphology and ecology of these have been modified by marram. Pīngao, *P. billardierii* and *M.*

arenarius were observed in 1982 and 1999 respectively (B. Rance pers comm.), but not found in 2015.

Threats:

Invasion by weeds pose the main threat to this site, particularly lupin with native dune plants recorded only in the few areas that remain free of lupin. Lupin is abundant at the northern end of the barrier but remains relatively sparse at the southern end although it forms large patches in places. Marram is widespread and occupies close to 100% of available habitat, but appears relatively sparse compared to our observations of marram on the Otago Peninsula and on Stewart Island. We found one gorse plant which should be eradicated as soon as possible. *Hieracium* spp. is abundant on the sand spit. Thistle is also present.

Potential for restoration:

The potential to recreate a sequence from active dune through to forest dominated with native plant communities, the formation of clear management units by the definition of the dune system by the Tautuku River and headlands, and the retention of large populations of threatened native dune plants increases the restoration ranking of this site. The southern portion of the site, particularly the spit, contains a diversity of dune landforms and habitat types, and the potential to restore dune processes here is high.

Site: Waipati Beach

Location: -46.61°Lat, 169.36°Long

Inventory Rating: 18

Photo: M. Moore, 2015

Description:

Prograded barrier similar in form to Tahakopa Bay and Tautuku Beach. Landforms comprise a discontinuous narrow and low (1.5m high) incipient foredune seaward of higher established foredunes in the north of the bay. Incipient foredune vegetation communities dominated by marram, established foredune vegetated with coastal forest/shrub. Erosion has prevented incipient foredune formation in places. Here the seaward dunes comprise a gently sloping and semi-vegetated seaward face of the established foredune. This dune zone is narrow, from 5m in the north of the bay widening to 30m in the south. Mobile dune forms including dune slacks present inside the Waipati River mouth. Lupin is present here.

Values:

Waipati Beach, as at Tahakopa Bay and Tautuku Beach, contains a now rare sequence of plant communities from active sand dune (albeit now dominated by non-native plants) through to late successional stage coastal forest. *C. acerosa* was recorded by Johnson (1992). Our observations at the nearby Tahakopa Bay and Tautuku Beach sites suggest that this species is likely to persist at Waipati Beach in areas that remain free of lupin.

Threats:

Invasion by weeds pose the main threat to this site. Marram is dominant and lupin is likely to be widespread based on our observations at Tahakopa Bay and Tautuku Beach.

Potential for restoration:

The potential to recreate a sequence from active dunes through to forest dominated by native plant communities raises the restoration ranking of this site. However, the difficulties with land tenure,

combined with the lack of landform diversity at most of this site and the narrowness of the dune systems, reduces the site's status. If restoration were to occur we would recommend that management be focussed on the relatively sparsely vegetation dunes within the mouth of the Waipati River. A range of landforms types is present here and the potential to restore mobile dune processes appears reasonably high. This area also seems the most likely to support remnant populations of native dune plants.

Site: Long-Dummies Beach

Location: -46.62°Lat, 169.26°Long

Inventory Rating: 16

Photo: M. Moore, 2015

Description:

This evaluation covers Long-Dummies Beach, as well as small bays to the north and south.

The site comprises a series of small bays with low foredunes seaward of forested hills. The vegetation communities are dominated by marram.

Values:

Pīngao and *Euphorbia glauca* were recorded here in 2011 (B. Rance pers. comm.). This is the only recorded occurrence of *E. glauca* in the Catlins region. *C. acerosa* was reported by Johnson (1992). Our observations at the nearby Tahakopa Bay and Tautuku Beach sites suggest that *C. acerosa* is likely to persist in areas that remain free of lupin.

Threats:

Marram is widespread. Lupin present in places. Grazing has resulted in the loss of dune integrity since 2005 (M. Hilton pers. obs.).

Potential for restoration:

The potential to recreate a sequence from active dune through to forest dominated with native plant communities raises the restoration ranking of this site. While the remaining populations of pīngao and *E. glauca* at this site should be conserved, other sites in the Catlins/Southland region are higher priorities for restoration due to their increased size and geomorphic complexity.

Site: Porpoise Bay

Location: -46.64°Lat, 169.11°Long

Inventory Rating: 9

Description:
The distal end of the spit is administered by DOC (Waikawa Harbour Conservation Area and marginal strip). The remainder is private land.

The site is a long bay, with a single high hummocky foredune (4-6m) seaward of pasture. A narrow, low incipient foredune terrace is present towards the central and northern end of the bay. Dunes have been recently eroded by waves, forming an erosion scarp along the length of the bay. The dune zone widens at the mouth of the Waikawa River. Here it is comprised of a progradation series of foredune ridges. Vegetation cover on the most recent two ridges is relatively sparse with minor blowouts and mobile dune forms present.

Sand dunes on the north-east shore of the Waikawa Harbour received an Inventory ranting of 11. This site was not visited during the current survey. Aerial photographs show a densely vegetated system largely indistinguishable from adjacent farmland.

Values:
Few values remain. Dunes are grazed to the sea and vegetated with marram, lupin and pasture grasses. No native dune species were observed.

Threats:
Plant communities are dominated by non-native species. Dune morphology has been modified by historic gold dredging and more recently by marram. Dunes are grazed.

Potential for restoration:
Few values to restore. Highly modified, albeit the dunes at the mouth of the Waikawa Harbour retain some natural dune processes. Geomorphic processes here could potentially be restored through the removal of marram, however, other sites have a higher restoration value.

Site: Haldane Bay

Location: -46.66°Lat, 169.05°Long

Inventory Rating: 7

Description:
A large transgressive dune system. Administered by DOC (The Reservoir, Haldane Conservation Area).

Landforms comprise parabolic dune forms now largely stable with marram and/or pasture. The dunes are distinctive due to their alignment parallel to the coast. The long axis of most parabolic dunes is normally oriented at 60 to 90 degrees to the adjacent coastline. At Haldane Bay the prevailing westerly winds have formed dunes at an acute angle to the coast, and sand has transgressed the headland at the eastern end of the bay.

Hilton (2000) noted several areas of bare, mobile sand in the inland areas of the dune system between Haldane Bay and Blue Cod Bay (to the east). Stock grazing the vegetation cover has probably contributed to this sand movement. More recent photography shows numerous blowouts along the coast, some which extend 35m inland. Comparison of aerial photographs suggests that these features are fairly stable, with little change in the size or shape of these features since 2005.

The foredune is currently eroded. A wave-cut scarp runs for most of the length of the eastern half of the bay. Several washover features are present at the mouth of the Haldane Estuary.

Values:
Few ecological values. Two small patches of pīngao were recorded by Johnson (1992) but it is unlikely that these remain given our observations at other beaches within the Catlins region over the past 20 years.

The size of the system means it can support a variety of dune environments. Geomorphically the dunes are of interest as a record of environmental change along the south east coast of New Zealand. Soils in the inland dune areas suggest that landforms here pre-date European activity. Midden containing moa bone date these dunes as at least 400-500 years old. These values are being degraded as grazing destabilises these dunes.

Threats:
Dunes are vegetated by marram, lupin and pasture grasses. Stock graze the dunes with negative impacts on both ecological and geomorphic values.

Potential for restoration:
Marram control and restoration of a 'natural' dune dynamic is achievable at Haldane Bay, but there are higher priorities within the region. Conservation of the older parabolic dune landforms should be considered, and could be achieved through improved farming practises and/or the planting of marram.

Site: Waipapa Beach

Location: -46.65°Lat, 168.90°Long

Inventory Rating: 14

Description:

Dunes between Waipapa Point and Blackpoint were evaluated, although relic dune landforms do extend beyond the assessed area. As at Haldane Bay the prevailing alongshore (westerly) winds have blown sand up and over the headland at the eastern end of the bay. The parabolic dunes here are relict features - fully vegetated and stable. They are of geomorphic interest but retain no dunal ecological values.

The site is administered by DOC east of Lake Brunton (Waipapa Beach Conservation Area).

The width of the dune system increases from west to east from 40m near Waipapa Point to 70m at the Black Point headland. The outlet of Lake Brunton towards the centre of the beach divides the dunes into two units. West of Lake Brunton dunes are high (15m) and hummocky. A 3-5m high wave-cut scarp runs for the length of this portion of the bay. Marram forms a continuous but relatively sparse vegetation cover. Lupin is widespread but patchy. Dune forms east of Lake Brunton were extensively modified by gold dredging in the 1930s. This operation created a large dune slack (wet depression). Marram dominates plant communities with large areas of lupin, particularly near Lake Brunton. Dunes along the seaward margin are sparsely vegetated and the foredune is comprised of shadow dunes and minor blowouts. Inland dunes are densely vegetated and stable. Adjoining land is pastoral.

Values:

Waipapa Beach retains extensive populations of native dune plants, notably *C. acerosa* and *P. lyallii* which seem able to coexist with marram. Small populations of *Rauolia aff. hookerii*. are present in sandy patches to the west of the Lake Brunton. These are under immediate threat of invasion by lupin. We observed two, relatively moribund, plants of pīngao. It is likely that more are present. We

observed no large colonies, however, so those that do remain will be scattered and growing among marram.

The dune system is of sufficient size to support a range of dune habitats. The dune slack area, although originally formed by a gold dredge, is the largest dune slack in the Catlin region, and indeed Southland and is likely to be nationally significant (B. Rance pers. comm.).

Threats:

Plant communities are dominated by non-native plants. The spread of lupin and/or gorse pose the most immediate threat to the ecological values of this site. Pasture grasses have invaded the more stable inland areas of the dune, and are often associated with lupin. Marram is widespread and probably occupies close to 100% of available habitat. Vehicle tracks were observed, but these seemed to follow a few well formed pathways. We observed sheep tracks in the dunes.

Potential for restoration:

The potential to restore this site is high. It retains significant populations of important dune species and supports a range of dune environments. Restoration should be focussed initially east of Lake Brunton within the DOC reserves where most values are retained.

Site: Waipapa Point

Location: -46.66°Lat, 168.84°Long

Inventory Rating: 11

Photo: M. Hilton, 2008.

Description:

The site comprises dunes along the coast running north-west from Waipapa Point Lighthouse to the mouth of the Toetoes Harbour. Landforms comprise parabolic dunes transgressing gentle coastal slopes. Dunes are stable, in pasture or vegetated with marram, lupin and/or gorse. Land in the vicinity of the lighthouse administered by DOC (Waipapa Point Recreation Reserve).

Values:

Pīngao has been planted near the lighthouse. Coastal turf communities are present. The site is a haul-out site for sea lions. There are few ecological dunal values away from the lighthouse. Dune landforms are of geomorphic interest, similar to those at Haldane Bay.

Threats:

Dunes are grazed and vegetated with marram, lupin and pasture grasses.

Potential for restoration:

There is limited potential for widespread restoration. Dunes are predominantly pastoral with little ecological integrity. Some restoration works have occurred near the lighthouse, namely the reintroduction of pīngao and these should be maintained. There is the potential for further restoration works within the DOC reserve but there are higher priorities within the District. This is a popular tourism site and so the potential for advocacy work exists.

Site: Fortrose Spit

Location: -46.57°Lat, 168.74°Long

Inventory Rating: 17

Description:

The site is a large sand spit enclosing the lower Mataura River. The western-most end of the Fortrose Spit beach is composed of a pea gravel storm beach grading into sand towards the eastern end. Dune forms comprise a low, steep foredune ridge, seaward of extensive deflation surfaces, dune hollows and stable back dunes. There are areas of estuarine vegetation along the edge of Toetoes Harbour.

Administered by DOC (Toetoes Harbour Spit Conservation area). Dune restoration work (translocations and weed control) have occurred in central part of the Spit since the late 1980s. Bythell and Rance (2014) provide an excellent overview of the values and threats to the spit.

Values:

This site is recognised as one of the most intact dune systems remaining on the southern Southland coast (Bythell and Rance 2014). It is notable for its diversity of habitats and its relative intactness. It retains a high number of native dune plants, mostly where DOC has removed marram although these species also persist where marram remains (Bythell and Rance 2014). It is likely that banded dotterel use the area. Skinks have been recorded from Fortrose Spit (Bythell and Rance 2014). The area is known to be an important habitat for invertebrates, notable Lepidoptera (i.e. moths and butterflies) (Bythell and Rance 2014).

Threats:

We observed numerous vehicle trails (ATVs and trail bikes) although vehicle management appears to be improving. The low growing cushion plant species (*Raoulia* aff. *hookeri*, for example) are particularly vulnerable to physical stress. Invasion by weed species threatens the values of the spit, as does browse by rabbits. Invasion by stonecrop and lupin pose particular threats to the *Raoulia*

mat/daisy herbfields.

Potential for restoration

This is an exceptional site with very high potential for restoration. This site is unusual in the Murihiku Region in that it has been the focus of ongoing restoration works. These works appear very successful with large populations of native dune plants remaining where marram and other species have been controlled. The 'island' nature of this site means that restoration works at this site could be expanded to progressively include the whole of the Spit.

Site: Tiwai Beach

Location: -46.60°Lat, 168.45°Long

Inventory Rating: 10-13

Description:
Not visited. The following descriptions come from the Inventory and analysis of Google Earth Imagery.

Long coarse sand and gravel beach with few dunes, mostly in the west. Where present sand dunes comprise a narrow band of low dunes. Google earth imagery from 2015 indicates that recent erosion by waves has formed a dune scarp in places.

Largely administered by DOC (Tiwai Spit Conservation Area, Marginal Strip, Waituna Wetlands Scenic Reserve).

Values:
Relatively few dune values dune to the limited area of dunal environment, however several threated and at risk dune plant species have been recorded here (appendix 3). The Awarua Barrier is an exceptional example of a progaded sequence of beach ridges and is of significant geomorphic value.

Threats:
Plant communities are dominated by marram and other weed species (gorse, lupin) are liqly to also threaten the values of this site.

Potential for restoration:
Marram control is achievable at Tiwai beach, but there are higher priorities within the region. Conservation of the significant remnant dune plant species should be considered, particularly of those species which have a restricted distribution elsewhere in the region. Conservation of the beach ridge landforms which comprise the greater Awarua Barrier should also be considered, but these at present are not threatened.

Site: Three Sisters Dune

Location: -46.54°Lat, 168.23°Long

Inventory Rating: 14

Description:

Complex transgressive dune system comprised of mobile dune forms blown 130m high and 1.3km inland over adjacent hill country. Landforms include parabolic dunes, sandy basins, and stony lag deposits supporting a range of plant communities. Streams flowing through the dunes have formed damp dune flats with coastal turf in places.

Marram dominates the coastal margins, dominating a zone up to 130m wide and 7m high. Pīngao unusually remains in the foredune in places. Marram has displaced pīngao from the foredune in most other dune systems in south-east New Zealand.

Native dune plants are widespread on the inland dunes. Pīngao forms large vigorous colonies and a large number of native dune plants are present. Marram, lupin, gorse and hieracium form scattered but large colonies.

A similar dune system is located 3km to the south. This site was not visited. Examination of recent aerial photography and discussions with B. Rance indicate that this dune has been highly modified by farming activities and invasion by non-native species. Few dunal values remain and the potential for restoration there is low.

Values:

This site has the most threatened plants of any in Southland (20 threatened taxa recorded) (B. Rance pers. comm.). It retains one of the largest populations of pīngao on mainland New Zealand south-east coast. It retains an unusual level of active dune processes (primarily wind transport of sand), due probably to the sparseness of marram on inland dunes. The retention of active dune processes creates a diversity of landforms and associated mosaic of habitats.

Threats:

The spread of non-native plants, particularly marram, lupin, and gorse threatens the exceptional ecological values of this site. At present lupin and gorse form relatively small colonies and could be relatively easily controlled. Marram is more extensive; however the DOC marram eradication programme on Stewart Island has shown that larger populations of marram can be successfully eradicated. The dominance of marram close to the coast poses the greatest threat to the medium-long term resilience of this site. Marram is trapping sand in the foredune which would otherwise be transported into the inland parts of the dunes by wind. This transfer of sand from the beach inland is essential for the maintenance of ongoing active dune processes, the associated diversity of dune habitats, and hence the survival of those species associated with those habitats.

Potential for restoration:

The potential to restore this site is high. It retains exceptional populations of important dune species and supports a range of dune environments. This site is one of the most significant dune systems remaining on the New Zealand south-east mainland coast.

Site: Oreti Beach

Location: -46.40°Lat, 168.20°Long

Inventory Rating: 5-6

Description:
A long sandy beach with steep-faced marram dominated foredunes. These foredunes increase in height from 1m in the north to 8m in the south. The deliberate planting of marram and construction of sand fences has resulted in a progradational sequence of up to 5 foredune ridges in the south. Along the remainder of the bay foredunes exist as only one or two ridges. Foredunes are backed by extensive, now stable, transgressive dunes. These are planted in pines, farmed and used for various recreational pursuits. Some remnant Totara forest patches remain. Transgressive dune forms, dominated by marram, gorse and pasture, are also present on the south coast of the New River Estuary. Parts of this dune are administered by DOC (Mokomoko Inlet Conservation Area).

Values:
Few dunal values. Dunes here are highly modified.

Threats:
Dunes dominated by marram. Disturbed in places by vehicles.

Potential for restoration:
Limited potential for restoration. Few dunal values remain and dunes are highly modified.

Site: Colac bay

Location: -46.35°Lat, 167.91°Long

Inventory Rating: 11

Description:
Coarse sand and gravel beach with relatively minor transgressive dune forms in the east of the bay. Dunes comprise narrow marram foredune with some, now stable, transgressive dune forms in the centre of the bay.

Values:
Few dunal values. The relatively high Inventory rating is due to plant communities associated with the gravel beach rather than dunes.

Threats:
Dunes are dominated by marram.

Potential for restoration:
Limited potential for restoration. Dune forms are minor and highly modified.

Site: Kawakaputa Bay

Location: - 46.36°Lat, 167.83°Long

Inventory Rating: 13

Description:

Mixed sand and gravel beach with a low marram dominated foredune along most of the western portion of the bay. In the eastern portion of the bay dune forms are transgressive in nature extending inland. The dunes of the eastern half of the Bay comprise two types — a geomorphically active foredune bordering the beach and, secondly, stabilised parabolic dunes 100-900m inland. Foredunes are steep with the minor blowouts characteristic of marram dominated dunes on high energy beaches.

Values:

From a geomorphic perspective the dunes of Kawakaputa Bay are of national interest as an example of a composite barrier. They are fossil features, in that they are now stabilised by marram grass and pasture grasses. The dunes are dominated by marram and retain few ecological values.

Threats:

The main threats are exotic plants and grazing by stock and rabbits

Potential for restoration:

Low priority for restoration given the high degree of modification and limited ecological values of this site.

Site: Te Waewae Bay

Location: - 46.20°Lat, 167.631Long

Inventory Rating: 7

Description:
Long gravel beach backed by sedimentary cliffs. Marram forms low dunes in places but overall few dune forms.

Values:
Few dunal values.

Threats:
Dunes are dominated by marram.

Potential for restoration:
Limited potential for restoration. Dune forms are minor.

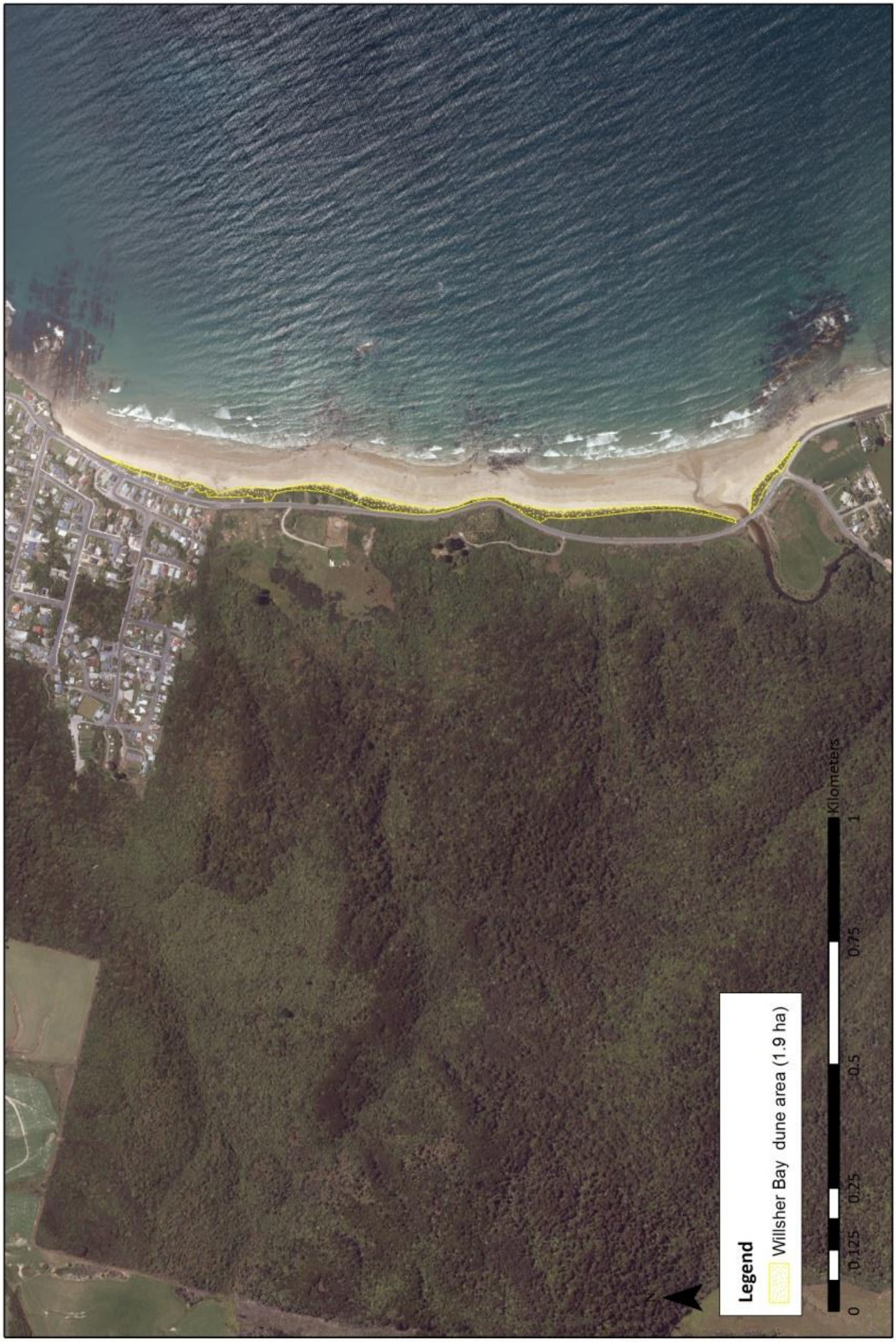
Appendix 2: Individual site maps

Sites visited by the author during May – July 2015 mapped only. Imagery dates from 2012-2014. Source: LINZ Data Service https://data.linz.govt.nz/layer/1910-otago-075m-rural-aerial-photos-2004-2011/ and licensed by Otago Regional Council for re-use under the Creative Commons Attribution 3.0 New Zealand licence, and GoogleEarth.

Dune areas identified from the most recent available satellite and aerial imagery. Proposed restoration areas identify the general area where the first stage of restoration works is recommended. At all sites the restoration area should be progressively increased to encompass the entire bay.

Clutha River Mouth

Willsher Bay




Surat-Cannibal Bay
N
Legend
Surat-Cannibal Bay dune area (82.0 ha)
Surat-Cannibal Bay potential sea lion habitat restoration
Surat-Cannibal Bay observed native dune plants
Kilometers
0
0.2
0.4
0.8
1.2
1.6
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Purakaunui Bay

Helena Falls Beach


Tahakopa Bay
N
Legend
Tahakopa dune area (8.6 ha)
Tahakopa proposed restored area (4.3 ha)
Tahakopa gorse
Tahakopa pingao
Tahakopa other native dune plants
Kilometers
0
0.175
0.35
0.7
1.05
1.4
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

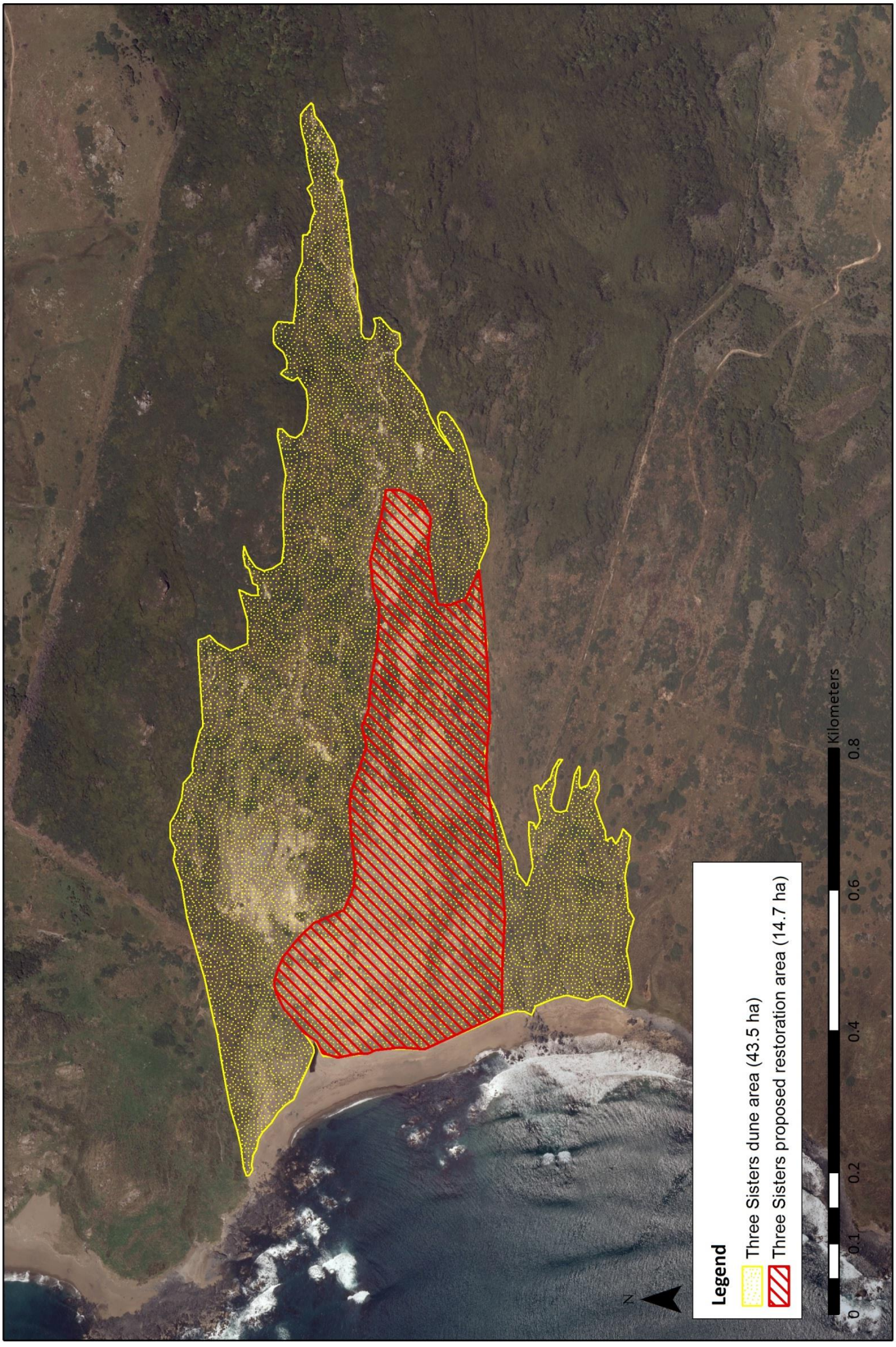

Tautuku Bay
N
Legend
Tautuku dune area (25.8 ha)
Tautuku proposed restoration area (12.6 ha)
Tautuku midden
Tautuku thistle
Tautuku gorse
Kilometers
0
0.25
0.5
1
1.5
2

Porpoise Bay


Waipapa Beach
N
Legend
Waipapa dune area (202.4 ha)
Waipapa proposed restoration area (60.6 ha)
Waipapa area surveyed
Waipapa dune slack
Waipapa pingao
Waipapa raoulia
Kilometers
0 0.25 0.5 1 1.5 2

Fortrose Spit

The Three Sisters




Kawakaputa Bay
Legend
Kawakaputa dune area (106.8 ha)
Kilometers
0
0.2
0.4
0.8
1.2
1.6
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Appendix 3: Threatened and At-Risk plant list, Murihiku District

Source: Brian Rance, Department of Conservation - Technical Advisor Ecology and Ecosystems

Species	Site (beach or dune system)													Number of sites per species (recorded since 2000)
	Cannibal –Surat Bay	Takahopa	Tautuku	Waipati	Long/ Shades	Haldane	Waipapa	Waipapa Point	Fortrose Spit	Tiwai	Tiwai Point	Three Sisters	Riverton Back Beach	
Nationally Critical														
Gunnera hamiltonii														1
Nationally Vulnerable														
Libertia peregrinans		*												2
Ranunculus recens														2
Declining														
Coprosma acerosa	*	*	*				*		*					8
Euphorbia glauca														2
Ficinia spiralis		*					*		*					6
Geranium sessiliflorum var. arenanium	*	*	*				*		*					8
Gunnera arenaria														2
Lepidium tenuicaule														
Mentha cunninghamii														1
Myosotis pygmaea									*					5
Poa billardierii									*					2
Raoulia sp. aff. hookerii	*						*		*					6
Relict														
Atriplex billardierii														
Naturally uncommon														
Acaena microphylla var. pauciglochidiata														3
Chaerophyllum sp. "coastal"														2
Euchiton polylepis														3
Euphrasia repens														1

Lachnogrostis ammobia														1
Leptinella serrulata														1
Leptinella traillii ssp. pulchella														1
Lobelia arenaria														2
Mazus arenarius														3
Pimelea lyallii	*	*	*				*		*					5
Senecio carnosulus														2
Wahlenburgia congesta														1
Data Deficient														
Epilobium insulare														1
Pimelea prostrata var. ventosa														1
Locally notable														
Acaena pallida	*													2
Brachyglottis rotundifolia														1
Deyeuxia billardierii														1
Ileostylis micranthus														1
Linum monogyna														1
Olearia nummularia														1
Species per site (recorded since 2000)														
	9	7	3	0	2	0	9)	1	10	9(11)	1	25	5	

Key

Present (recorded since 2000)

Historic record (recorded between 1980 -2000)

Present in adjacent coastal sites

* Observed this survey (Note: no systematic vegetation surveys were conducted)