Inventory of New Zealand's active dunelands

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Dedication

This study is dedicated to John Holloway, former Director, Science & Research, Department of Conservation. John's early encouragement ensured the current study reached fruition.

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ABSTRACT

An inventory of active dunelands in New Zealand, those dunelands that owe their physical, landscape and ecological character to the ongoing or very recent movement of sand by wind, is presented. Maps of active dunelands for the 1950s, 1970s and 1980s for each region were derived from published topographic maps and other historic sources. Maps showing the extent of active duneland in the 1990s were derived from the most recent aerial photographs held by local authorities. The boundaries of active dunelands were digitised at the map or photo scale and stored as a geographic information system database using ARC-INFO software. ARC-INFO was used to calculate the area of each active duneland, sum the areas of active duneland in each region and produce A4 format maps of active duneland cover in the 1950s, 1970s, 1980s. and 1990s for each region and for subdivisions of each region. Maps were circulated to Department of Conservation and local authority offices and corrections made where necessary.

The national area of active duneland in New Zealand, around 129 000 ha in the early 1900s, has been reduced to about 39 000 ha; a 70% reduction. The area of active duneland has declined in all regions; however, those regions that once contained the largest areas of active duneland (e.g. Northland, Auckland, Manawatu) have experienced the greatest decline. The decline in the total area of duneland has probably continued through the late 1990s, but at a reduced rate.

The main cause of the decline in area of active duneland has been the stabilisation, then afforestation, of active dunelands. Other activities, including agricultural development, sand mining, urbanisation, uncontrolled grazing by stock, waste disposal and military activities have caused local degradation, but account for a minor proportion of the area of active duneland lost. The opportunity for preserving the remaining conservation values of active dunelands may not extend far beyond the first decade of the 21 st century.

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1. Introduction

Coastal dunelands are widespread around the New Zealand coast. The largest areas occur along the Manawatu, Auckland and Northland coasts, but dunelands, from a few square metres to thousands of hectares in area, are found throughout New Zealand. Cockayne described them as New Zealand's 'most common landform' and hailed them as being of special scientific importance. He saw in New Zealand:

'an opportunity of observing what nature, quite unhindered, has done for their fixation. The native dune plants are also of much interest, since some are endemic and also of quite remarkable form, while their value as "sand fixers" is by no means generally appreciated'. (Cockayne 1911, p. 4)

This inventory is concerned with those active dunelands that owe their physical, landscape and ecological character to the ongoing or very recent movement of sand by wind. In the main they contain significant areas of bare sand or semi-vegetated sand. Vegetation is dominated by grasses, sedges and herbs, many peculiar to the active dune environment. Mature podocarp forest; areas of muttonbird scrub *(Senecio reinoldii);* gorse *(Ulex europaeus);* manuka *(Leptospermum scoparium);* plantation forest (mostly *Pinus radiata*) and kanuka *(Leptospermum ericoides)* shrubland on stablised duneland are not included in the current inventory. Small areas of these vegetation types may, however, have been mapped where they occur within larger areas of active duneland. A wide range of habitats occur within the active dunelands mapped, many of which are local equivalents of the dune ecosystem complexes proposed by Olsen et al. (1989). These include incipient foredunes and foredunes composed of recently blown sand; scrub growth on active, recently stabilised, or overblown substrate; stonefields; moist dune slacks and wetlands; coastal turf on a range of substrates including rocky outcrops within larger active dunelands and dune lakes.

The majority of active dunelands now bear little resemblance to Cockayne's early descriptions. Human occupation of New Zealand has had a significant impact on the natural character of these dunelands. The influence of early Maori occupation on dune flora has not yet been fully examined. In most regions the effects were probably quite localised, but some authors interpret widespread dune disturbance. For example, Coster (1989) presents a three-phase model of settlement and environmental change for the Aupouri Peninsula, once one of the largest active dunelands, in which he ascribes the formation of the mobile western dune belt to Maori influence, namely the disturbance of the native vegetation cover by fire.

Widespread disturbance of New Zealand's dunelands occurred following European settlement (Taylor & Smith 1997). The vegetation cover of dunes throughout the country was disturbed by fire and grazing, which triggered the expansion of some dunelands and loss of adjacent agricultural land. Marram grass *(Ammophila arenaria),* a vigorous sandbinder, was imported from Europe via Australia soon after the publication of Cockayne's 1911 report and planted throughout New Zealand to both stabilise dunes and initiate the process of afforestation of dunelands with *Pinus radiata.* Stabilisation and afforestation

resulted in the widespread loss of habitat for many native plant and animal species. Sand mining, stock grazing, infrastructure development, urbanisation and the introduction of a wide range of exotic plant, shrub and tree species (e.g. *Acacia sophorae*) contributed to the widespread degradation of the natural character of active dunelands.

The contribution of active duneland to the natural character of the New Zealand coastal environment received belated recognition in the New Zealand Coastal Policy Statement (Department of Conservation 1994, Policy 1.1.2) which identifies the protection of dunes as a matter of national importance. Community and government awareness of the tenuous conservation status of many active dunelands is, however, very low. Relatively few are being actively managed for conservation purposes by either local authorities or the Department of Conservation. Most dune restoration programs initiated by local authorities aim to reestablish foredunes for the purpose of coastal hazard management, rather than the conservation of dune function or dune flora. The ongoing eradication of marram grass on Stewart Island by the Department of Conservation stands as perhaps the most significant dune conservation initiative to date, although there are several other important projects.

Biological inventories are a fundamental requirement of biodiversity conservation strategies (Norse 1993). In New Zealand, however, there is relatively little published information on the flora and fauna of dunelands, active or stabilised, the location of dunelands, the conservation status of dunelands or trends in duneland condition. The Sand Dune and Beach Vegetation Inventory of New Zealand (Johnson 1992, Partridge 1992), the Coastal Resource Inventories prepared by the Department of Conservation in the early 1990s, and occasional Protected Natural Areas Programme reports (e.g. Ravine 1992), have provided valuable information on the general state of the duneland environment and the conservation status of particular dunelands. There remains, however, uncertainty as to the remaining area of active duneland, the location of individual dunelands and trends in the decline in such areas in each region.

The present study aims to locate and map remaining active dunelands with the intention of producing a comprehensive national inventory. This inventory is intended to compliment the 'state of the environment' monitoring initiatives of local authorities arising from section 35 of the Resource Management Act 1991, and the Environmental Performance Indicators program of the Ministry for the Environment (1997), by providing a base for subsequent work on the ecology and conservation management of active dunelands. Further, the study aims to reveal trends in the loss of active duneland in each region and provide a basis for detailed classification, mapping and monitoring of associated habitats, flora and fauna. The strengths and weaknesses of existing duneland inventories are discussed.

2. Previous inventories

2.1 LEONARD COCKAYNE (1911, 1958)

The first extensive survey of New Zealand's coastal sand dunes was undertaken by Cockayne (1911). The work was commissioned by the Minister of Lands at a time when transgressive dunes and sand sheets were considered a threat to the productivity of adjoining agricultural lands and some infrastructure, particularly in the Manawatu and Northland Regions. The Sand Drift Act 1907 had only recently been enacted. Cockayne's brief was to describe the botany and general character of New Zealand's dunes and to recommend methods of dune stabilisation and afforestation.

Cockayne recognised a range of 'dune plant associations', including semi-vegetated dunes dominated by the native sand binders (pingao, *Desmoschoenus spiralis;* spinifex, *Spinifex sericeus*), stabilised dunes with grass, shrub or forest cover and inter-dune wetlands and lakes. He estimated the total area of 'dune' in 1911 to be 128 740 ha of which 118 900 ha was located in the North Island and 9840 ha in the South Island and Stewart Island. He did not explain how these estimates were derived or which dune habitats were included or excluded. The wording of the 1911 report strongly suggests Cockayne excluded established shrub and forest on stabilised dunes but included the range of habitats associated with the more active dunes to seaward (e.g. interdune wetlands). Cockayne also provided estimates of the area of dunes in each region (as regions were defined in 1911). Estimates of the total area of duneland were repeated in 'The Vegetation of New Zealand' (Cockayne 1958) with minor changes (New Zealand-127 000 ha; North Island-117 300 ha; South Island-9700 ha).

An aside-it may seem ironic, given his awareness of the 'special scientific importance' of New Zealand dunes and dune plants that Cockayne should conclude 'the final treatment of dunes should assuredly be afforestation' (Cockayne 1911, p. 4). But in this context he was probably referring to the sand drift problem, which was the main reason for preparing the dune report. Marram grass was introduced to stabilise and revegetate those areas of denuded wandering dunelands that were increasing in size as they migrated inland (pers. comm. Trevor Partridge 1998). Cockayne could not have foreseen that marram grass would be widely planted in almost all active dunelands, regardless of their condition. Unfortunately, marram grass proved a particularly aggressive invader and rapidly spread beyond the many sites where it was planted. So, on the one hand, marram grass offered a solution to problems of sand movement; on the other it has forever changed the natural character of most of New Zealand's active dunelands.

New Zealand had been occupied by Europeans for most of a century when Cockayne described the country's dunelands. To what extent had their natural character been affected by first Maori and later European settlement and subsequent disturbance? In particular, what was the relative importance of natural/anthropogenic processes contributing to the expansion of active dunelands around New Zealand? This question is important because it concerns the extent to which the natural character of the New Zealand coast has been

lost as a result of dune stabilisation. It is germane to this study because it is not clear whether the area of active duneland present in the early 1950s is the result of natural processes or not. Was the widespread expansion of active dunelands described by Cockayne the result of natural processes (climatic variation, for example)? Or was it largely or completely the result of human activity? This conundrum is clearly beyond the scope of the present study, but several facts point to the climatic hypothesis:

1. Dunelands clearly experienced episodes of destabilisation and expansion during the Late Holocene prior to the arrival of people (McFadgen 1989).
2. Duneland expansion has occurred in historic times at sites relatively unaffected by human activity (e.g. Mason Bay, Stewart Island).
3. Active duneland development during the late Holocene has been remarkably uniform down the west coasts of Northland and Auckland despite the localised impacts of people (e.g. South Kaipara Peninsula, Hilton 1982).

There are also many cases where particular dunes have been degraded as a result of vegetation disturbance by people in historic times (e.g. McGlone 1983, Enright & Anderson 1988). However, on balance, it is likely that the widespread stabilisation of New Zealand's active dunelands documented in the present study has substantially interfered with the natural development of these dunelands. Until the matter is resolved it is important to note that the first maps and aerial photographs of New Zealand's active dunelands, on which the current study is based, followed over a thousand years of human occupation and localised disturbance of some of New Zealand's active dunelands.

2.2 NEW ZEALAND LAND RESOURCE INVENTORY

An inventory of sand-dune communities was derived from the New Zealand Land Resource Inventory (NZLRI) and other sources and mapped at a scale of 1:1 000 000. Sand dune communities were defined as 'communities dominated by herbaceous plants and low shrubs occurring on recent, unstable dune sands' (Newsome 1987, p. 130). The communities so mapped apparently exclude stable, backdune, habitats dominated by woody shrub and tree species.

Because of the large map scale employed only the larger active dunelands were recorded, including those of the Aupouri Peninsula, North and South Kaipara Peninsulas, Awhitu Peninsula, Pakiri Beach, the active dunelands bordering the Aotea and Kawhia Harbours, the Manawatu coast, Farewell Spit, Oreti Beach and Mason Bay. Many smaller active dunelands, particularly those along the east coast of New Zealand, were omitted. The maps of active dunelands were derived from data collected during the 1960s and 1970s for the NZLRI (NWASCO 1975-79). The total area of active duneland corresponding to the above definition was estimated to be 52 000 hectares. A further 40 000 ha of backdune, dominated by exotic lupins *(Lupinus arboreus)* and shrubs, were identified. Approximately 200 000 ha of 'former dunes' were described as being covered in pasture grasses, pine trees, gorse and other exotic species (Newsome 1987). Of the 305 000 ha of coastal sand dunes identified in the New Zealand Land Resource Inventory (NWASCO, 1975-79) less than 10% were considered to be still close to their original condition (Hunter & Blaschke 1986).

2.3 THE PROTECTED NATURAL AREAS PROGRAM

The Protected Natural Areas Program has provided valuable information on the botanical characteristics and conservation status of certain dunelands (e.g. Foxton Ecological District, Ravine 1992). The Program was established with the intention of recording the location and characteristics of indigenous plant communities in the knowledge that many remaining communities of high conservation value are poorly represented in the existing reserves system. Recommended Areas for Protection (RAPS) are assessed on the basis of representativeness, diversity, special features, naturalness, viability, size and shape and buffering from external stresses. The boundaries of RAPS are delineated on NZMS 260 maps at a scale of 1:50 000.

Most published PNA Program survey reports that include stretches of coastline have identified RAPS containing areas of active or stabilised duneland. These are mostly fragments of duneland within much larger areas of modified duneland (e.g. Turakina Estuary Spit, Foxton Ecological District) but in some instances are large, relatively intact and natural, areas (e.g. Whatipu, Waitakere Ecological District). Unfortunately, relatively few ecological districts have been surveyed since the pilot surveys of 1983. There are a total of 179 ecological districts (EDs), 104 in the South Island and offshore islands and 75 in the North Island. Of these 123 contain stretches of coast. As of April 1998 only 33 PNA Program reports had been published (pers. comm. Dr Colin Ogle, Department of Conservation) and only 25 of the 123 coastal ecological districts had been surveyed (18 in the North Island, 7 in the South Island). Ecological districts known to contain significant remnants of largely unmodified duneland, active and forested, have yet to be surveyed. These include Te Paki ED, Kaipara ED, Ellesmere ED, Fiord Ecological Region (Fiordland) and those ecological districts containing the north and west coasts of Stewart Island. Such has been the (slow) pace of the PNA Program that important mainland active duneland sites are likely to be lost to marram grass invasion or other stresses before they are surveyed.

2.4 THE SAND DUNE AND BEACH VEGETATION INVENTORY OF NEW ZEALAND

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, Partridge 1992) provided the first national survey and conservation assessment of New Zealand's dunelands (with an emphasis on active dunelands). The aim of the survey was to identify the dune systems with the highest natural values (particularly botanical values) so that these might be included in New Zealand's reserve system.

Field surveys were carried out in an incremental fashion by regional botanists of the Botany Division between 1984 and 1988 using a simple rating system. Dunelands were ranked between 0 and 20 based on the diversity of communities and landforms; number or proportion of native sand species; degree of human or animal modification of the site and degree of invasion by weed species.

The Inventory resulted in the identification of 23 North Island, 21 South Island and 9 Stewart Island sites as priority dunelands for conservation (Table 1) (Figure 1). Some regions have no sites considered of national significance (e.g. Bay of Plenty) while others have a significant number (e.g. Southland has 13). The majority of sites occur in the far north of the North Island and far south of the South Island, in Fiordland and along the north and west coasts of Stewart Island. The majority of priority sites fall within the jurisdiction of just four local authorities (Northland Regional Council, Southland Regional Council, The Far North District Council and the Southland District Council). The Department of Conservation has responsibility for the management of the 9 priority dunelands on Stewart Island, the 10 dunelands in Fiordland, as well as other dunelands that fall within the conservation estate.

Rapson (1996) concluded that the national Sand Dune and Beach Vegetation Inventory understates the ecological importance of many dunelands and criticised the methodology for failing to adequately recognise interdune wetland and lake habitats, for missing rare species and for missing particular dunelands. The survey was, however, never meant to be comprehensive, but sought, rather, to indicate those sites worthy of more detailed investigation and conservation management (Partridge 1992). It is now some 15 years or so since the majority of dunelands were surveyed. Many sites, particularly those not recognised as being of national significance, but which still possessed

TABLE 1. NATIONAL PRIORITY SITES FOR CONSERVATION, SAND DUNE AND BEACH VEGETATION INVENTORY OF NEW ZEALAND (JOHNSON 1992, PARTRIDGE 1992). DUNE RATING (/20) SHOWN IN PARENTHESES.

NORTH ISLAND (23 sites)	
Northland	Spirits Bay (18), Ponaki Beach (13), Taeore to Paxton Pt (17), Waikuku Beach (16), Tom Bowling Bay (16), Te Werahi Beach (16), Twilight Beach (15), Ngamaru Pt (14), Rarawa Beach (14), Ocean Beach (14), Black Rocks to North Head (14), Kawerua to Maungonui Bluff (13)
Auckland	Omaha Beach (14), Pakiri Beach (13)
Waikato	Waikawau Beach (16), Otama Beach (16), Hot Water Beach (13)
Bay of Plenty	Matakana Island (14)
Taranaki	Waipingau Stream (13)
Manawatu-Wanganui	Harakeke Dunes (15), N. of Foxton Beach (13)
Wellington	Te Humenga Pt. (14), Porangahau South (13)
SOUTH ISLAND (30 sites)	
Tasman	Farewell Spit (15)
Westland	Saltwater Lagoon (15), Okarito Beach (16), Ohinemaka River (16)
Canterbury	Kaitorete Spit (18)
Otago	Tahakopa Bay (18), Tautuku Bay (18)
Southland	
Fiordland	Cascade River (18), Barn Bay (18), Big Bay (16), Martin's Bay(17), Transit Beach (17), Poison Bay (17), Sutherland Sound (17), Catseye Bay (16), Coal River (19), Te Whara Beach (15)
South Coast	Waipati Beach (18), Longbeach and Dummy's Beach (16), Toetoes Harbour Beach (17), Sand Hill Point (16)
Stewart Island	Smoky Beach (20), Three-legged Woodhen Bay (16), Doughboy Bay (16), Mason Bay (18), Little Hellfire (15), Big Hellfire (19), Sealer's Bay (15), West Ruggedy (16), East Ruggedy (18)

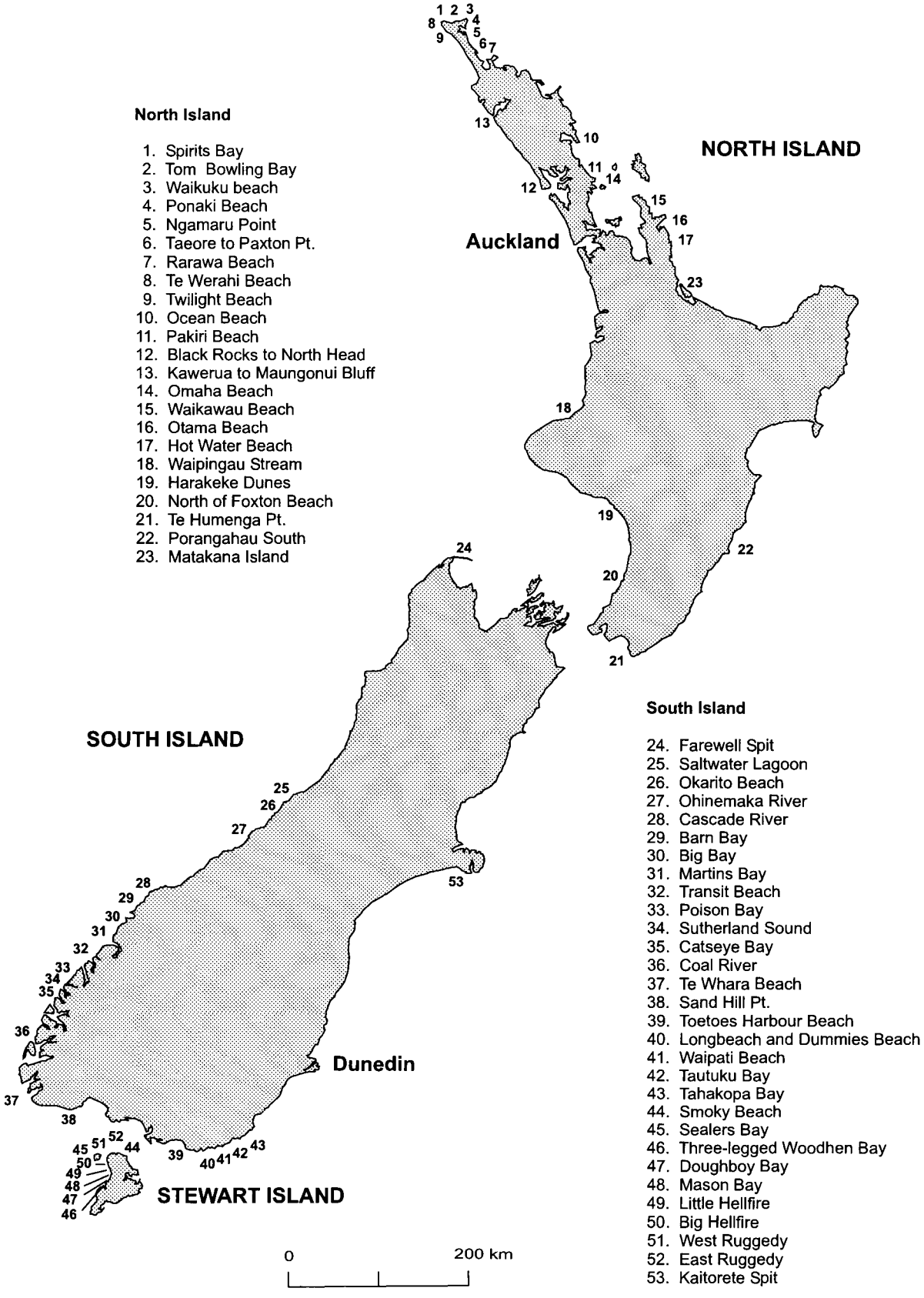

Figure 1. National priorities for duneland conservation (Sand Dune and Beach Vegetation Inventory, Partridge 1992, Johnson 1992).

significant conservation values, have since been degraded. Some are now almost completely modified-the native flora and fauna have been lost to marram grass, rabbits, deer or stock (e.g. Long Beach, Otago).

The aims of the Sand Dune and Beach Vegetation Inventory and the PNA Program clearly overlap-both seek to identify areas of duneland containing native vegetation of high conservation value. A comparison of the results of both studies shows, however, some significant differences. The Foxton PNAP survey report, for example, identifies seven RAPs containing duneland habitat, mostly foredune habitat. Some other RAPs contain a range of plant communities associated with stabilised duneland, dune lakes, estuarine salt marsh and other dune-related habitats. Of the seven RAP dune sites only one, the area of active duneland north of Foxton Beach, was ranked highly in the Sand Dune and Beach Vegetation Inventory as a 'national priority area for conservation'. The second Manawatu site ranked highly in the Inventory, the Harakeke Duneland, is the highest ranked duneland in the Manawatu (rank = 15) but was not identified in the PNAP survey report as a RAP. The Inventory gives a relatively high ranking to two other active dunelands not identified in the PNAP report: the dunes northwest of the Waitotara River (10) and south of the Hokio River (11). The Inventory tends to undervalue active dunelands that have low diversity of communities and high levels of weed invasion, albeit they exhibit high native floral diversity or may contain threatened species. The criteria adopted by the PNA Program may also exclude dunelands of significant conservation value. A duneland may exhibit 'special features' and a high level of 'naturalness' but receive low scores for 'viability, size, shape, and buffering from external stresses'. Most active dunelands, even those containing exceptional native dune flora, are unlikely to be viable where marram grass is present without intensive management. Many remnants are also now very small.

It is difficult to reconcile the known conservation status of certain coastal plant species in some regions with the Inventory's list of national priority areas for conservation. For example, at least six plant species associated with active dunelands are identified in the Otago list of threatened and local plants (Johnson 1993). These are *Austrofestuca littoralis* (described as being rare); *Desmoschoenus spiralis* (local); *Euphorbia glauca* (vulnerable); *Libertia peregrinans* (uncertain); *Pimelea arenaria* (rare); and *Schizeilema cockaynei* (local). Areas of active duneland containing specimens of these plants must be of at least regional if not national significance and so worthy of recognition and protection. At what point in the decline of New Zealand's active duneland flora will authorities consider it necessary to embark on species-led recovery programmes? Will sufficient information be available to make a timely decision?

The Sand Dune and Beach Vegetation Inventory discusses dune-plant associations and describes the floral characteristic of the strandline, foredune, backdune, moist inter-dune depressions and stone pavements. In general, site rankings appear to be based on the botanical characteristics of these environments: the Inventory places less importance on dune forest on stabilised duneland (for example, the Otatara totara forest at Oreti Beach, Southland) and wetlands within, or adjoining, dunelands. The PNAP surveys have involved more systematic investigation of the plant communities of an ecological district and so, predictably, recognise plant communities on older dunes, within and on the margins of active dunelands, including wetlands and dune forest.

Partridge (1992) explains the decision to conduct an independent survey of beach and dune vegetation on the grounds that the dune habitat is not easily covered by the PNAP surveys. The results of the Foxton survey suggest otherwise. The Sand Dune and Beach Vegetation Inventory provided, for the first time, a timely study of the relative conservation value of almost all New Zealand's dunelands. The PNAP has provided a more accurate description and assessment of the conservation status of dunelands at a regional level, but very few dunelands have so far been surveyed. The PNAP surveys have also provided information on the plant communities established on stabilised backdunes, while the Inventory has focused on habitats dominated by or associated with the major sandbinders (i.e. the active dunelands).

2.5 SUMMARY OF PAST INVENTORIES

In summary, there have been two major surveys of New Zealand's active and stabilised dunelands. The New Zealand Beach and Dune Vegetation Inventory, despite methodological limitations, has provided the only consistent, nation-wide, assessment of their conservation status. This inventory did not map the boundaries or area of individual dunelands, active or stabilised, and some of the results are now out of date. The Protected Natural Areas Program surveys have provided some detailed site information, mapped dunelands of high conservation value and recommended sites for protection, but, to date, very few dunelands have been surveyed.

Data drawn from the New Zealand Land Resources Inventory have been used to derive maps of remaining active dunelands, but the maps exclude many important areas. There is a clear need for a new national inventory of the location of remaining active dunelands. There is also a need to undertake an analysis of the rate of decline in the area of active duneland in each region as a result of afforestation, urbanisation and other pressures. The current paper seeks to add to our understanding of the conservation status of New Zealand's remaining active dunelands by mapping, using the most recent aerial photography, the location and area of remaining active dunelands and to undertake an analysis of regional trends in the rate of loss of active duneland.

3. New Zealand dune environments

The dunelands of New Zealand display remarkable morphological diversity in response to regional and local variations in sediment supply, climate, hinterland topography and vegetation. Individual dunelands may contain a wide range of active and relict dune forms reflecting episodic development of active duneland. The dunelands of the Foxton Ecological District on the west coast of the Manawatu, for example, reveal actively migrating dunes have been present for at least the last 6500 years. Cowie (1963) interpreted four phases of dune building: less than 120 yBP; up to 1000 yBP; 2000-4000 yBP; and 10 000-20 000 yBP (Cowie 1963). Subsequent work has identified two major pulses of dune development at the coast during the late Holocene: 6500 to 4500 yBP and 3500 to 1300 yBP (Muckersie & Shepherd 1994). The latter study concluded landward movement of dunes continued long after the period of dune initiation at the coastline had ceased.

The combination of dunes of different ages gives rise to marked intra-duneland variation in soil type, soil moisture, substrate stability, exposure to wind and wind-blown sand and other environmental parameters, resulting in a complex of dune habitats. Cockayne (1958, p.92) recognised the inter-relationships between dune environment and habitat in early descriptions of New Zealand's dunelands:

'Dune-vegetation exhibits a gradual procession of events in harmony with the increasing stability of the substratum, the foredune marking the unstable commencement and the fixed inland sand-hill the stable climax. Stages also occur where a new class of association branches off that may be merely transitory or become permanent, their persistence depending upon the stability of the dune-area as a whole.'

Cockayne identified several plant communities associated with different types and ages of dune more or less correlated with increasing distance from the sea: 'sand grass dune' (dominated, in pre-marram times, by either *Desmoschoenus spiralis* or *Spinifex sericeus*; 'shrub-dune' (developed in association with sand-trapping shrubs such as *Coprosma acerosa*); 'fixed-dune' (covered in various grasses and shrubs); 'hollows and sand-plains' (containing a range of species favouring moist substrates including *Gunnera arenaria* and *Leptocarpus similis*); 'ancient dunes' and 'dune-forest' (containing various podocarp tree species). Such a sequence can still be described at Mason Bay, Stewart Island and in fragments along the Manawatu coast.

The range of terms used in past studies suggests the ecological interpretation and classification of New Zealand's active and stabilised dunelands is at a very early stage of development compared with typologies developed for European dunes. Olson et al. (1989), for example, have presented a coherent classification of dune landforms, local dune ecosystems, dune systems and sandy coasts for the description and understanding of the landscape ecology of European dunes. Apart from the foredune habitat there appears to be little consistency in New Zealand in the description of dune landforms and habitats. The recent publication of an overview of the form and function of coastal dunes by Hesp (2000) should greatly assist the adoption of a standard terminology.

4. Methodology

The methodology employed in the present study involves compiling a GIS database of active dunelands from available maps, photographs and other sources and circulating the draft maps for checking by local authority and Department of Conservation conservancy and field centre staff. Feedback and revision of the maps should be an ongoing exercise.

A range of information from different sources was collected in order to identify and map past and remaining active dunelands (Appendix 1). These included aerial photographs, topographic maps, soil maps, the Coastal Resource Inventory (CRI), the Sand Dune and Beach Vegetation Inventory (Johnson 1992, Partridge 1992), survey reports of the Protected Natural Areas Programme (e.g. Denyer et al. (1993), proposed regional coastal plans (e.g. ARC, 1995), published reports (e.g. Waitakere Ranges Protection Society, 1978), scientific papers (e.g. Cowie 1963) and dissertations (e.g. Hilton 1982), and various regional and specialist inventories (e.g. Campbell et al. 1982). The CRIB and Sand Dune and Beach Vegetation Inventories identified (but did not map) most remaining active dunelands.

Maps of active dunelands for the 1950s, 1970s and 1980s for each region were derived from published topographic maps (Appendix 1). Some very detailed maps of dunes were published as NZMS 2 at a scale of 1:25 000 in the early 1950s based on field work dating from 1943, however, the series was abandoned before at least half the maps had been published. These maps were particularly valuable in mapping the post-war active dunelands of the Aupouri Peninsula and other active dunelands, including the Mahia Peninsula and Oreti Beach. Other duneland maps for the 1950s, 1970s and 1980s were derived from NZMS 1 (1:63 360) or NZMS 260 (1:50 000) with additional data derived from soil maps.

The 1990s maps of active duneland are derived from the most recent aerial photographs held by local authorities. Most regional councils have flown low level vertical, colour, aerial photographs of their coasts since 1993. The Manawatu-Wanganui Regional Council, for example, obtained 1:27 5000 color aerial photographs of their coast between May 1995 and May 1997. The Department of Conservation holds some additional recent aerial photography. Comprehensive aerial photography was not available in four regions-Auckland, Wellington, Marlborough District and the West Coast and estimates for these regions are derived from a range of published and unpublished sources including planning maps.

The boundaries of active dunelands were digitised at the map or photo scale and stored as a geographic information system database using ARC-INFO software. Map data was converted from transverse mercator projection to New Zealand Map Grid and regional and sub-regional maps generated. ARC-INFO was used to calculate the area of each active duneland, sum the areas of active duneland in each region and produce A4 format maps of active duneland cover in the 1950s, 1970s, 1980s and 1990s for each region and stretches of coast within regions. Individual maps are compiled from map and aerial photograph sources that span

periods of time. Synoptic, aerial photographic coverage of the coastline has only recently been achieved in some regions. In most regions the 1950s to 1980s maps presented here are based on collections of photographs that may span months or even years.

The accuracy of the 1990s maps of active duneland may be examined in relation to the identification of individual active dunelands, the delineation of the boundaries of active dunelands and the degree to which regional trends in the decline or increase in the area of active duneland are revealed by the analysis. Feedback from Department of Conservation staff and local authority planning and science staff indicates the initial mapping based on the above sources successfully identified all but a few active dunelands. In some cases active dunelands present in the early 1990s have been afforested or otherwise destroyed. Delineation of the boundaries of active dunelands has been, in some cases, problematic, particularly where the aerial photographic coverage is poor and the active duneland/hinterland vegetation boundary is indistinct. In optimal conditions it has been possible to identify and map very small areas or very narrow strips of active duneland. The resolution of the database varies from a few metres to tens of metres, depending on the quality of the original data. The regional and sub-regional maps developed contain data digitised at a wide range of scales, but usually between 1:10 000 and 1:63 000.

The question of the degree to which the 1950s maps represent the pre-European and pre-Maori area of active dunelands has been mentioned. The earliest aerial photographs examined in the present study date from 1942. By this time much of the indigenous lowland vegetation cover of New Zealand had been cleared for pastoral agriculture and sheep or other animals were grazing areas of duneland. Marram grass had been introduced to many active dunelands, particularly those close to towns, roads or railway lines (e.g. St. Clair Beach, Dunedin; Woodhill, Auckland) but also to very remote dunelands (e.g. Mason Bay, Stewart Island). Dunes or adjacent beaches were being mined for building sand (e.g. Pakiri Beach, Auckland). Settlements were expanding over dunelands (e.g. Lyall Bay, Wellington). Areas of pingao and spinifex, the native sandbinders, were being fired, trampled or eaten by domestic stock. A range of exotic plant and animal species had colonised most, if not all, active dunelands. Finally, initial efforts were being made to stabilise areas of active duneland along the west coast of the North Island for plantation forestry (Sale 1985). These activities must have had some impact on the naturalness of New Zealand's active duneland, but were probably of minor importance when compared with the pressures of the last 50 years.

5. Results

5.1 DISTRIBUTION OF ACTIVE DUNELAND

Cockayne (1911) estimated the total area of active duneland as 128 740 ha, a value very similar to that derived from the 1940s/1950s maps of active duneland in the present study. The question of whether the active duneland present in the 1950s represents the natural area of active duneland, or a somewhat greater area following anthropogenic disturbance, has already been raised. Large areas of the Aupouri Peninsula and the North and South Kaipara Peninsulas, for example, were comprised of bare sand-in 1880 the area of 'drifting' sands on the Aupouri Peninsula was estimated at 16 000 ha (Sale 1985). The question of the origin of these and other extensive dunelands must await detailed site investigations of active duneland development at a wide range of sites. Related questions include:

1. Has the area of active duneland changed since human occupation of New Zealand?
2. Has the balance of native to introduced flora and dune habitats changed since the introduction of marram grass and other exotic species?
3. Has the balance of different dune habitats changed since human occupation (pers. comm. Trevor Partridge)?

Dunelands were present in all regions, though they were most extensive along the west coasts of the three main islands. Extensive active dunelands were present along the west coast of the Aupouri Peninsula and along the Manawatu coast south of the Wanganui River. The active duneland of the west coast of the Aupouri Peninsula in northern Northland extended alongshore approximately 80 km and inland approximately 5 km. Large areas of active duneland, of the order of kilometres in length and width, also occurred at other places along the west coasts of New Zealand, including the entrances to the harbours of the North Island (e.g. South and North Kaipara Peninsulas), Farewell Spit (Tasman District), Westport, Mason Bay (Stewart Island) and Long Beach (Chatham Island). Semi-continuous active dunelands tens to hundreds of metres in width stretched between these larger sites along the west coasts of the North and South Islands; however, relatively isolated and small active dunelands were also present (e.g. Waipingau Stream, Taranaki; Gates Creek, Westland; Coal River, Fiordland; and Little Hellfire, Stewart Island).

The active dunelands of the east coasts of the North and South islands, south coast (Southland) and north coast of Stewart Island generally occur within well-defined embayments. The active dunelands of the western Bay of Plenty are a notable exception-they form a semi-continuous belt between Waihi Beach and Ohope Beach, a distance of approximately 110 km. Almost all the east coast active dunelands are less than 1 km in width and many are only a few tens to a hundred metres in width. In the 1950s the larger east coast sites included Kokota Spit (Northland), Bream Bay (Northland), Pakiri-Mangawhai Bay (Auckland), Matakana Island (Bay of Plenty), Mahia Peninsula (Hawkes Bay), Porangahau (Hawkes Bay) and Pegasus Bay. Significant stretches of the east coasts have very few or very small dunelands, namely eastern Northland, the inner Hauraki Gulf, the eastern Bay of Plenty and the east coast of Stewart Island south of the Neck.

A full explanation of regional variations in active duneland geomorphology and ecology is beyond the scope of the current paper. Clearly there are major differences in duneland development between west (windward) and east (lee) coasts of the three main islands. The relatively greater size of west coast dunelands reflects New Zealand's location in the southern South Pacific in the prevailing westerly air stream and the size of coastal sand systems. East coast active dunelands are, in general, smaller, less dynamic and more clearly associated with local sediment sources. This is particularly so between North Cape and East Cape on the east coast of the North Island. The dunelands of the west and east coasts of the South Island, in contrast, receive sediment from northward alongshore sand transport systems generated by prevailing south and southwest winds and waves. The dunes of the south coast of Otago Peninsula, for example, are comprised of sediments delivered to the coast by the Clutha River, swept north along the inner continental shelf by southerly swell waves and across the foreshore by southerly winds. In contrast, the dunelands of the northeast coast of the North Island are largely associated with closed sand systems.

The earliest (1950s) and most recent (1990s) maps of active duneland for each region of New Zealand are presented in Appendix 2.

5.2 NATIONAL AND REGIONAL TRENDS IN ACTIVE DUNELAND AREA

The area of active duneland in New Zealand has undergone a striking decline since World War II (Table 2). In 1950 it was 129 402 ha. By the 1990s the area had been reduced to 38 949 ha; a reduction of about 70%.

TABLE 2. TRENDS IN AREA OF ACTIVE DUNELAND BY REGION.

REGION	1950s (ha)	1970s (ha)	1980s (ha)	1990s (ha)	% LOST
Auckland	15 223.84	8555.70	4812.50	NA	68.39
Bay/Plenty	1692.39	1363.65	982.26	928.14	45.16
Canterbury	5207.68	2075.10	1928.15	1846.10	64.55
East Coast	726.49	677.19	693.41	673.03	7.36
Hawkes Bay	2790.38	2614.47	1720.39	1441.70	48.33
Marlborough	379.46	379.46	247.37	NA	34.80
Nelson	NA	512.39	NA	NA	NA
Northland	64 199.43	38 348.38	24 728.13	15 180.92	76.35
Manawatu	16 627.08	8600.51	2636.41	2359.93	81.31
Otago	1775.01	1754.35	1075.52	1039.27	41.44
Southland	4854.55	4295.54	3894.75	3343.02	31.33
Taranaki	1471.46	1447.39	419.80	433.45	70.54
Tasman	3007.05	2577.75	750.44	654.81	78.22
Waikato	7168.14	4600.75	2155.92	2022.07	71.79
Wellington	984.89	982.64	914.086	NA	7.2
West Coast	2781.88	2435.99	2399.40	NA	13.75
Total	129 402	81 221	50 012	38 949	69.90

NA-Maps for some regions could not be prepared because of the lack of aerial photographs. The area of active duneland lost in the Auckland region is probably higher than measured.

All regions experienced a decline in the area of active duneland, however, the reduction has not been uniform. The Wellington region lost just 7% while the Manawatu Region has lost over 81%. Moreover, those regions that contained larger areas of active duneland in the 1950s are generally those that have lost the most (Northland, 76% lost; Auckland, 68%; Waikato, 72%; Manawatu, 81%) (Table 3).

The decline in the area of active duneland has continued throughout the post-war period, although at different rates. The area of active duneland in Canterbury declined by about 60% between the 1950s and 1970s, but thereafter experienced relatively little decline. In contrast, the area of active duneland in Otago showed little change until the 1970s, then declined rapidly. The area of active duneland in the Manawatu has remained relatively stable since the 1980s. Nationally, the rate of loss of active duneland has slowed.

The retention of a relatively large proportion of the original area of active duneland in some regions is notable given the national trend. Southland, incorporating Fiordland and Stewart Island, has lost 31% of the active duneland and the West Coast approximately 14% (Table 3). These regions accounted for 3.8% and 2.1% respectively of the post-War area of active duneland.

5.3 CAUSES OF THE DECLINE IN AREA OF ACTIVE DUNELAND

The decline in area of a particular active duneland is seldom the result of a single influence and it is beyond the scope of the present paper to examine the circumstances of individual dunelands or regions. The main cause of the decline in area of active duneland has been the stabilisation, then afforestation, of active dunelands. The Lands Department began planting marram grass soon after the publication of Cockayne's (1911) report with the intention of establishing production forestry on the dunes of New Zealand. The New Zealand Forest Service developed the technology needed to establish *Pinus radiata* on coastal sands and planted large areas of the Northland, Auckland, Manawatu and Waikato dunes during the 1960s, 1970s and 1980s (McKelvey 1999). The decline in active duneland along the Aupouri Peninsula following World War II is almost entirely the result of afforestation. Other activities, including agricultural development, sand mining, urbanisation, uncontrolled grazing by stock, waste disposal and military activities were of local importance, but account for a minor proportion of the area of active duneland lost.

TABLE 3. PROPORTION OF NATIONAL ACTIVE DUNELAND IN EACH REGION (1950) (RANKED BY AREA) AND PERCENTAGE LOST (1950s-1990s).

REGION	PROPORTION OF NATIONAL TOTAL IN 1950 (%)	PROPORTION LOST 1950s-1990s (%)
Northland	49.6	76.3
Manawatu	12.8	81.3
Auckland	11.8	68.4
Bay of Plenty	1.3	45.2
Waikato	5.5	71.8
Canterbury	4.0	64.5
Southland	3.8	31.3
Tasman	2.3	78.2
Hawkes Bay	2.2	48.3
West Coast	2.1	13.7
Otago	1.4	41.4
Taranaki	1.1	70.5
Wellington	0.8	7.2
East Coast	0.6	7.4
Nelson	0.4	NA
Marlborough	0.3	34.8

6. Discussion

The results of the present study support the early estimates of Cockayne (1911)-the area of active duneland dominated by the native sandbinders, including a range of dune habitats and affiliated plant species, was around 129 000 ha at the beginning of this century. Newsome's (1987) estimate of the area of duneland at around 52,000 ha accords with the results of this study for the late 1970s when the New Zealand Land Resource Inventory was published (NWASCO 1975-79).

The total area of active duneland had declined to around 39 000 ha by the early to mid 1990s. This is likely an overestimate of the current area of active duneland. The most recent aerial photography available for the Northland Region, which contained the largest area of active duneland, was flown in September 1993. Conversion of active duneland in this and other regions has likely continued since the aerial photography was obtained.

The current study documents the decline in area of active duneland, not the change in the area and diversity of particular dune habitats, ecological integrity or conservation status of individual areas. Many of the active dunelands mapped in the current study may now have little natural character due to marram grass invasion and other processes. The impact of marram grass is manifest in several ways. Perhaps the most serious is the potential for marram grass to reduce or prevent phases of instability that provide opportunities for specialist dune plant species. Marram grass forms a relatively dense vegetation cover that both accelerates the process of vegetation succession and prevents or inhibits instability. The impact of marram grass has been particularly severe on the east and south coasts of the South Island and west coast of the North Island. For example, the area of duneland in the Otago Region has declined by approximately 41%, a moderate loss by national standards. However, all but a few of the remaining areas are dominated by marram grass. In general, the active dunelands between Oamaru and the Catlin's coast were ranked lowly in the Sand Dune and Beach Vegetation Inventory and none were identified as being of national significance. Tahakopa Beach is the only area of active duneland in Otago retaining high natural values. The Department of Conservation initiated a program of marram grass eradication at Tahakopa in late 1999.

The Sand Dune and Beach Vegetation Inventory remains the only systematic, nation-wide, assessment of the conservation status of New Zealand's dunelands. The ranking method employed appears to have led to the identification of those active dunelands with exceptional natural values remaining in New Zealand. Many other active dunelands, though possessing significant conservation values (scoring, say, 3 for diversity of communities and landforms and a similar score for number or proportion of native species), were ranked low to moderate because of the presence of weeds or degree of modification. Many of these sites warrant active management to ensure representative examples of active duneland ecosystems are retained. Pingao, for example, exhibits significant variation in size and colouring around New Zealand (New Zealand Forest Research 1994) and it is important that local populations be maintained for use

in restoration projects and to supply weaving materials. It could be argued that almost any occurrence of pingao along the Otago coastline warrants conservation in terms of the conservation of genetic diversity and Treaty of Waitangi obligations.

The current study indicates that many of the remaining active dunelands are small remnants of previously much larger areas. Many of these fragments are of national significance, despite their area, in that they contain threatened or localised plants. There are now relatively few dunelands that contain the sequence of semi-vegetated, unstable dunes to stable, vegetated dunes described by Cockayne (1958)-at many sites the backdunes have been converted to forestry or some other use. The flora associated with more stable dunelands has, therefore, been particularly impacted by human activity.

Finally, our knowledge of duneland ecosystems in New Zealand is inadequate for management purposes. New Zealand urgently requires:

- an inventory of the remaining area of pingao and spinifex;
- a full classification and mapping of dune types and assessment of their natural character;
- an inventory of particular habitats and species associated with the general duneland environment, including dune lakes, inter-dune wetlands and dune forest;
- environmental performance indicators in relation to the management of active duneland habitats, especially indicators of the area of native and introduced sandbinding species (marram grass, pingao, spinifex); and
- an interpretation and biophysical classification of dune ecosystems to provide a basis for assessing the representativeness and conservation value of particular dunelands.

7. Conclusions

1. Active dunelands were present in all regions following World War II, though they were most extensive along the west coasts of the three main islands. Large areas of active duneland were present along the west coast of the Aupouri Peninsula with smaller areas along the Manawatu coast south of the Wanganui River. Large areas of active duneland, of the order of kilometres in length and width, also occurred at other places along the windward coasts of the main and offshore islands. Semi-continuous active dunelands, tens to hundreds of metres in width, stretched between these larger sites along the west coasts of the North and South Islands and Stewart Island. Relatively isolated and small active dunelands were present in all regions.
2. The national area of active duneland in New Zealand, around 129 000 ha in the early 1900s, has undergone a marked decline since World War 11. By the early 1990s the area had been reduced to about 39 000 ha, a 70% reduction.
3. The area of active duneland has declined in all regions; however, those regions that once contained the largest areas of active duneland have experienced the greatest decline. The area of active duneland in Northland, which contained almost half of the national total, has declined by 76%, mostly as a result of afforestation. The trends are similar in Auckland and the Manawatu.
4. The decline in the total area of active duneland has probably continued through the late 1990s, but at a reduced rate.
5. Existing duneland inventories, namely the Sand Dune and Beach Vegetation Inventory of New Zealand, the Coastal Resource Inventories and occasional Protected Natural Areas Program survey reports, have provided an overview of the decline in natural character of dunelands and identified active dunelands of exceptional conservation value. Further work is urgently required to develop a biophysical classification of active duneland habitats comparable with that developed for European dunes; to develop inventories of particular dune habitats (e.g. interdune wetlands) and threatened or local dune species; and to map and monitor the distribution of marram grass, pingao and spinifex and other native species and communities. Given the rate at which the area and naturalness of New Zealand's active dunelands have declined over the last 40 years or so the opportunity for preserving the remaining conservation values of active dunelands may not extend far beyond the first decade of the 21st century.

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Appendix 1

SOURCES OF ACTIVE DUNELAND DATA AND REGIONAL FILENAMES

REGION	1950s	1970s	1980s	1990s
Northland	1:63 360 NZMS1 1:25 000 NZMS 1957-1961 F:*aup1950*, *northl1950*[1]	1:63 360 NZMS1 1970-1976 F:*aup1970*, *northl1970*	1:50 000 NZMS260 1982-1983 F:*aup1980*, *northl1980*	Northland Regional Council Aerial Photography Ref. 235885 to 337169 23/7/93-6/9/93 F:*aup1990*, *northl1990*
Auckland	1:63 360 NZMS1 1:25 000 NZMS2 1942-1953 F:*auck1950c*	1:63 360 NZMS1 1965-1978 F:*auck1970c*	1:50 000 NZMS260 1978-1990 F:*auck198c*	Coastal Resource Inventory & Proposed Regional Plan
Waikato	1:63 360 NZMS1 1944-1957 F:*waik1950c*	1:63 360 NZMS1 1964-1981 F:*waik1970c*	1:50 000 NZMS260 1978-1987 F:*waik1980*	Waikato Regional Council Aerial Photography 1993 F:*waik1990*
Bay of Plenty	1:63 360 NZMS1 1944-1969 F:*bop1950*	1:63 360 NZMS1 1962-1979 F:*bop1970*	1:50 000 NZMS260 1979-1988 F:*bop1980*	Bay Of Plenty Proposed Regional Coastal environment plan. Volume 2 1991. Maps 3.1-3.50 F:*bop1990*
Gisborne	1:63 360 NZMS1 1944-1967 F:*cgisb1950*	1:63 360 NZMS1 1970-1982 F:*cgisb1970*	1:50 000 NZMS260 1983-1990 F:*gisb1980*	Gisborne Regional Council Aerial Photography 24/5/93 F:*gisb1990*
Hawkes Bay	1:63 360 NZMS1 1:25 000 MZMS 1943-1955 Aerial Photography HBRC 1942-1944 F:*chawk1950*	1:63 360 NZMS1 1955-1974 F:*chawk1970*	1:50 000 NZMS260 1978-1990 F:*hawk1980*	Hawkes Bay Regional Council Aerial Photography Obliques 1995. & 1:25 000, 1:5000 7/11/95 F:*hawk1990*
Taranaki	1:63 360 NZMS1 1942-1953 F:*ctara1950*	1:63 360 NZMS1 1965-1978 F:*ctara1970*	1:50 000 NZMS260 1978-1990 F:*tara1980*	Taranaki Regional Council Aerial Photography 27/11/93-9/5/94 1:27500 F:*tara1990*
Manawatu- Wanganui	1:63 360 NZMS1 1942-1953 F:*cmang1950*	1:63 360 NZMS1 1955-1976 F:*cmang1970*	1:50 000 NZMS260 1980-1987 F:*mang1980*	Manawatu-Wanganui Regional Council Aerial Photography 26/5/95-1/5/97 1:27500 F:*mang1990*

Wellington	1:63 360 NZMS1 1943-1957 F:*well1950c*	1:63 360 NZMS1 1965-1981 F:*well1970c*	1:50 000 NZMS260 1983-1987 F:*well1980*	
Tasman	1:63 360 NZMS1 1942-1962 F:*tas1950*	1:63 360 NZMS1 1946-1978 F:*tas1970*	1:50 000 NZMS260 1984-1987 F:*tas1980*	Tasman District Council & DOC aerial photography 1988-1995 F:*tas1990*
Nelson	1:63 360 NZMS1 1942-1944	1:63 360 NZMS1 1978-1980 F:*nelson1970*	1:50 000 NZMS260 1980-1987 F:*nelson1980*	Nelson Regional Council Aerial Photography 1994
Marlborough	1:63 360 NZMS1 1942-1945 F:*marl1950*	1:63 360 NZMS1 1964-1973 F:*marl1970*	1:50 000 NZMS260 1980-1985 F:*marl1980*	
Canterbury	1:63 360 NZMS1 1942-1950 F:*cant1950*	1:63 360 NZMS1 1968-1977 F:*cant1970*	1:50 000 NZMS260 1981-1991 F:*cant1980*	Canterbury Regional Council Aerial Photography 1991-1996 F:*cant1990*
West Coast	1:63 360 NZMS1 1943-1970 F:*west1950*	1:63 360 NZMS1 1962-1981 F:*west1970*	1:50 000 NZMS260 1979-1995 F:*west1980*	
Otago	1:63 360 NZMS1 1942-1966 F:*otago1950*	1:63 360 NZMS1 1965-978 F:*otago1970*	1:50 000 NZMS260 1980-1984 F:*otago1980*	Otago Regional Council Aerial Photography 21/9/96-3/5/97 1:27 500 F:*otago1990*

F: electronic file name (by region and decade). See also introduction to Appendix 2.

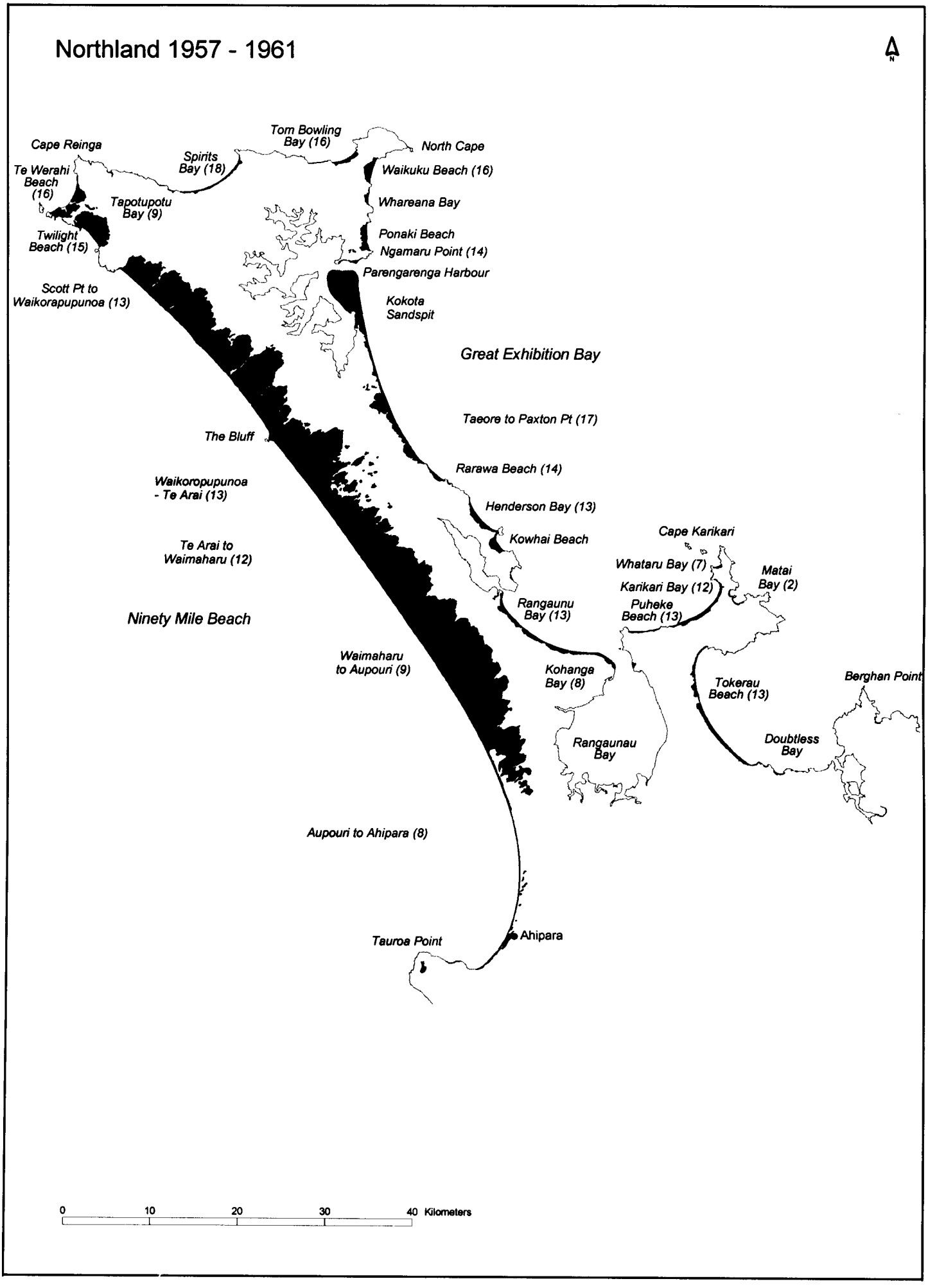
Appendix 2

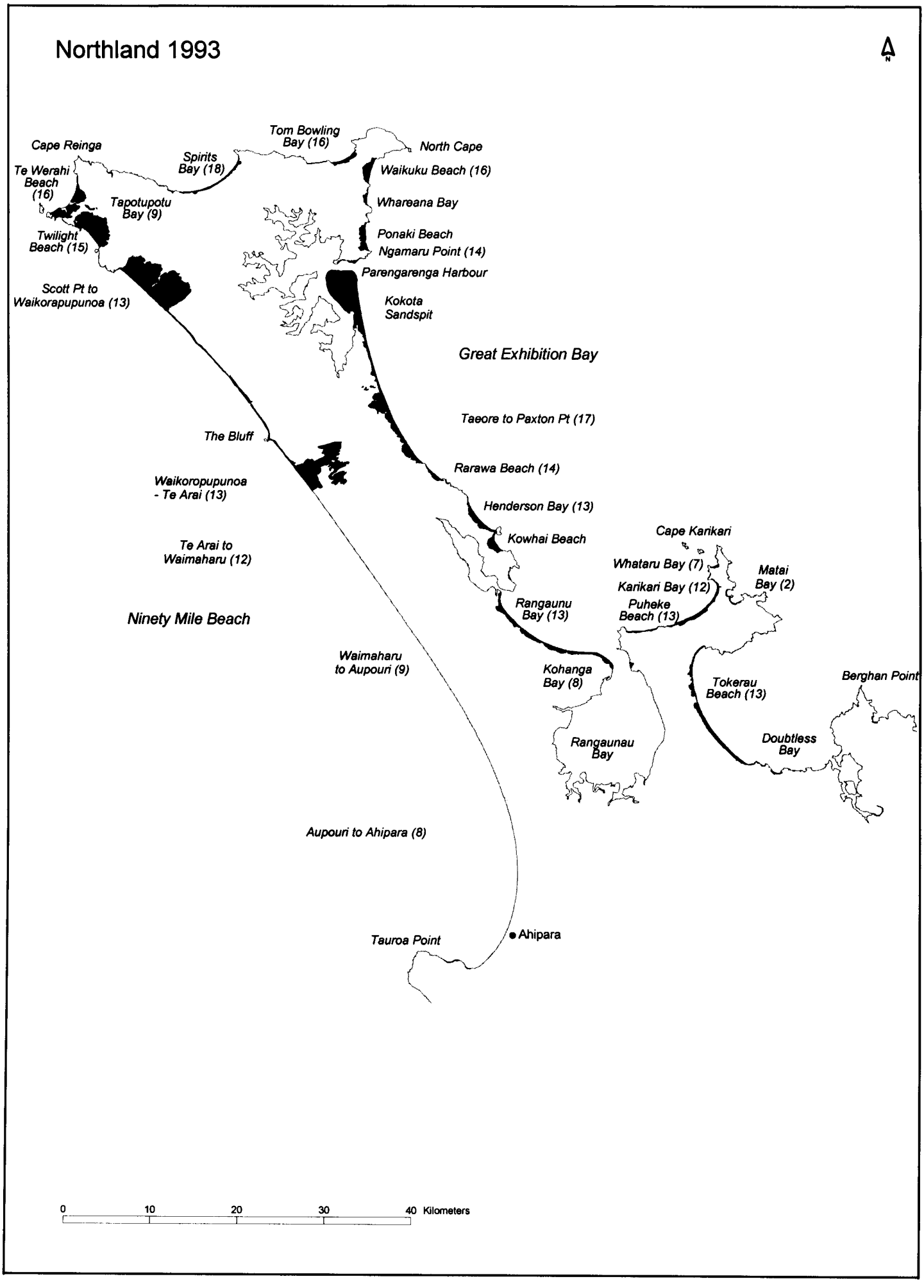
MAPS OF ACTIVE DUNELAND FOR EACH REGION (1950s TO 1990s). REGIONAL AND SUBREGIONAL MAPS ARE PRESENTED.

These maps present the earliest and most recent data on the location and area of active dunelands in New Zealand. The rating (/20) given in the Sand Dune and Beach Vegetation Inventories of Partridge (1992) and Johnson (1992) are given in parentheses. The term 'duneland' on these maps should be read as 'active duneland'.

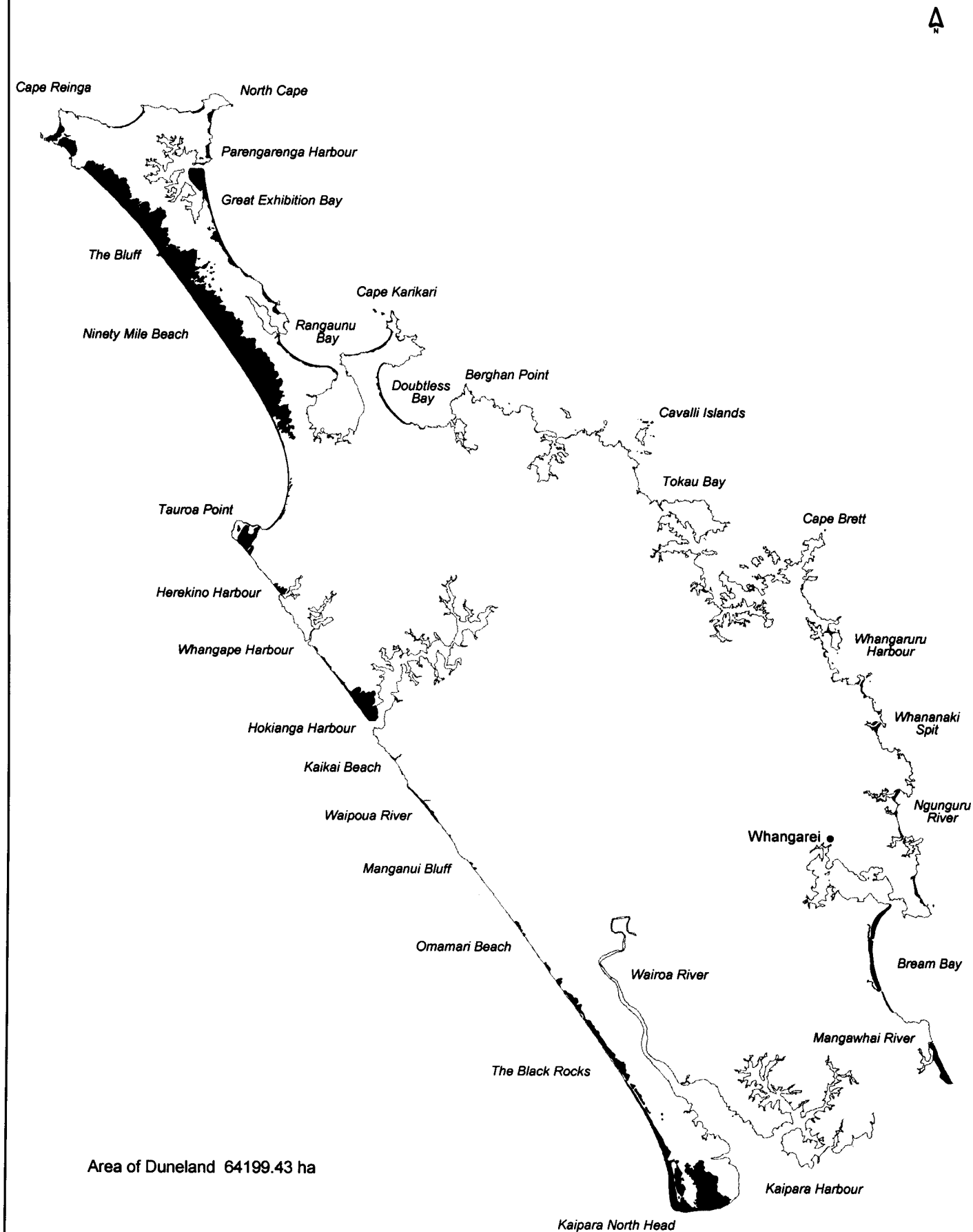
The printed maps are presented from the north to the south of the country, and from oldest (left-hand page) to most recent (right-hand page).

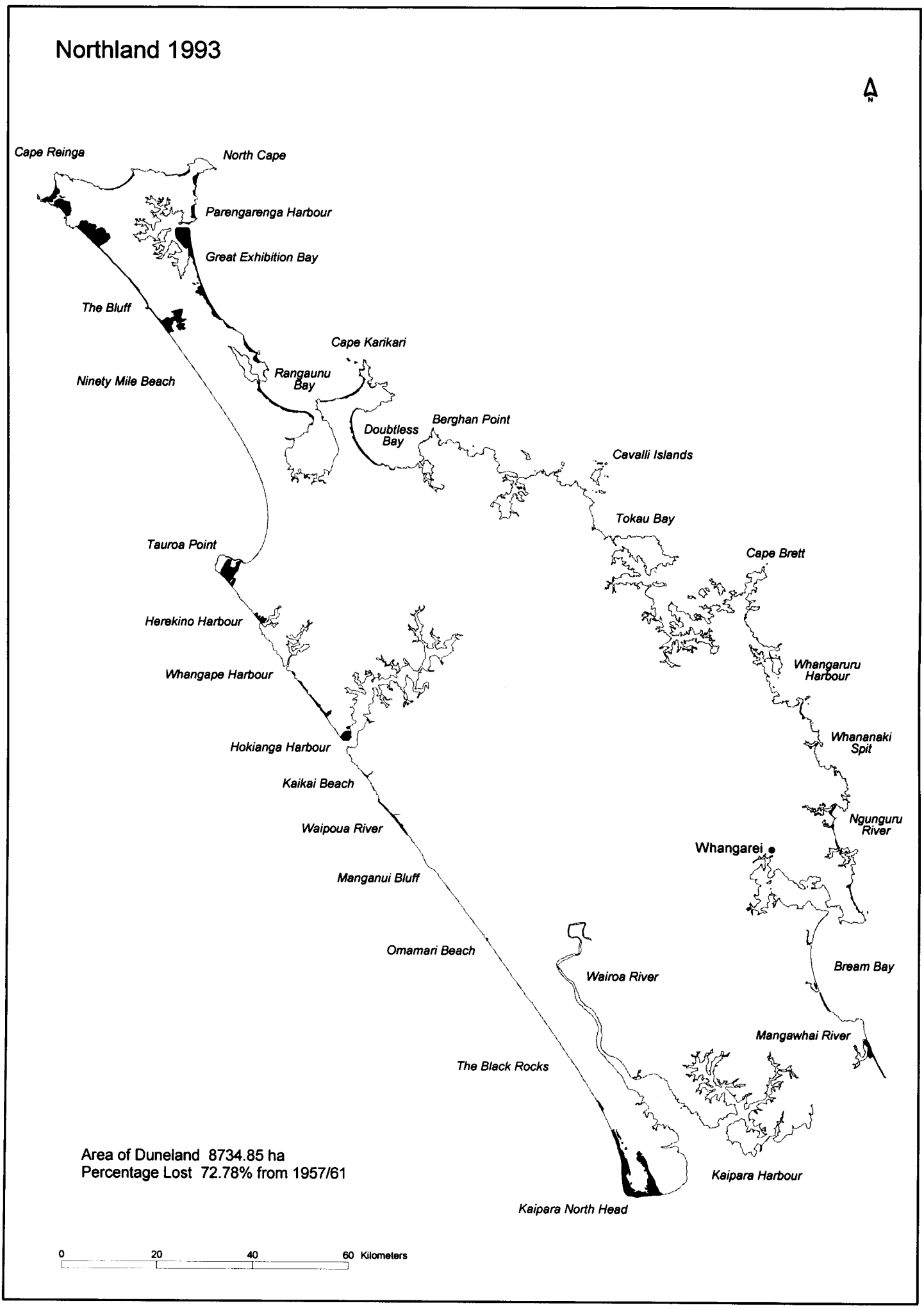
Electronic versions of all maps (see Appendix 1 for file names) are available by region in Arc View format on DOC's Intranet, or on disc.

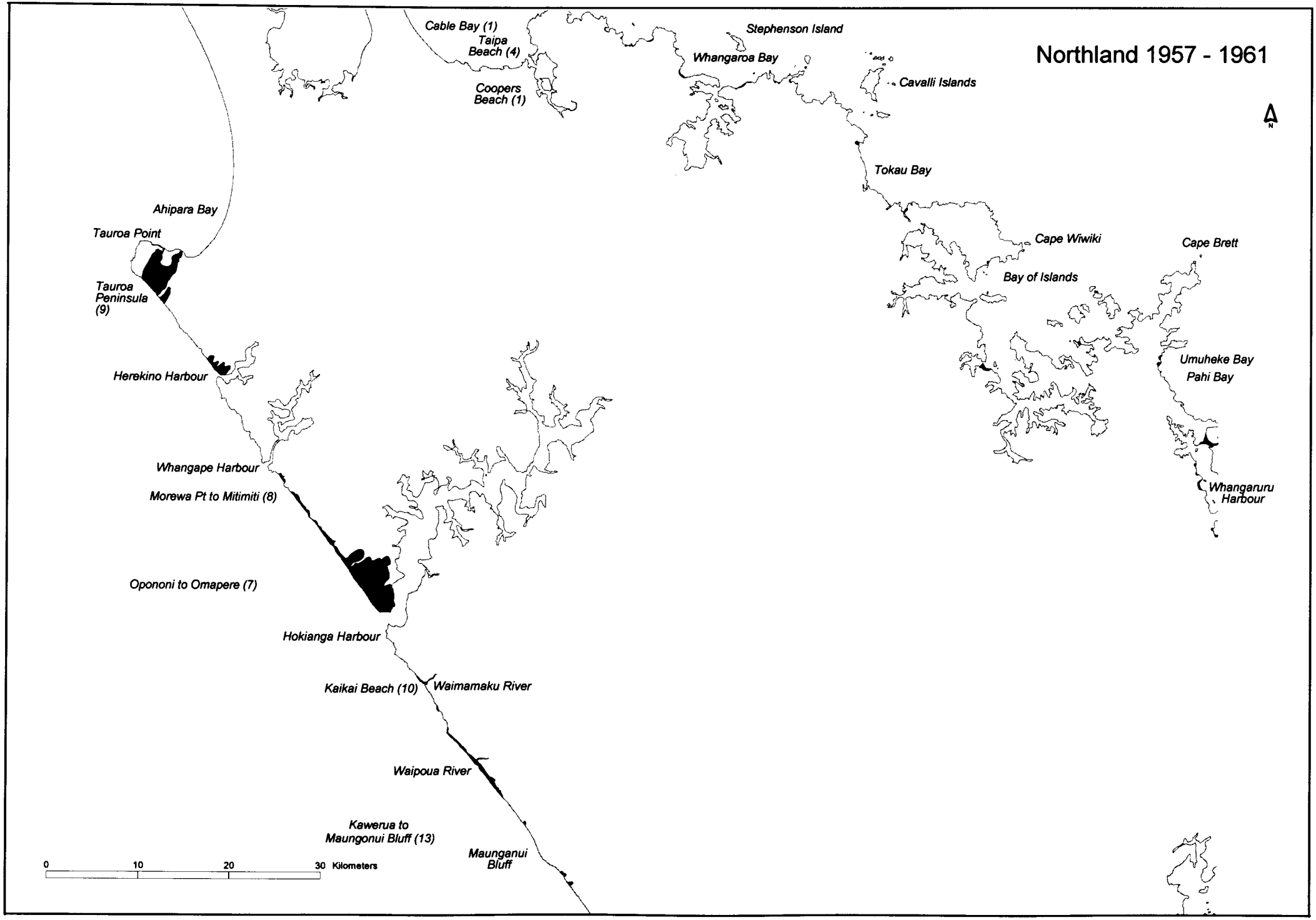

Northland 1957 - 1961
N
Cape Reinga
Tom Bowling Bay (16)
North Cape
Spirits Bay (18)
Te Werahi Beach (16)
Waikuku Beach (16)
Tapotupotu Bay (9)
Whareana Bay
Twilight Beach (15)
Ponaki Beach
Ngamaru Point (14)
Parengarenga Harbour
Scott Pt to Waikorapupunoa (13)
Kokota Sandspit
Great Exhibition Bay
Taeore to Paxton Pt (17)
The Bluff
Rarawa Beach (14)
Waikoropupunoa - Te Arai (13)
Henderson Bay (13)
Kowhai Beach
Cape Karikari
Te Arai to Waimaharu (12)
Whataru Bay (7)
Matai Bay (2)
Karikari Bay (12)
Rangaunu Bay (13)
Puheke Beach (13)
Ninety Mile Beach
Waimaharu to Aupouri (9)
Kohanga Bay (8)
Tokerau Beach (13)
Berghan Point
Rangaunau Bay
Doubtless Bay
Aupouri to Ahipara (8)
Tauroa Point
Ahipara
0
10
20
30
40 Kilometers

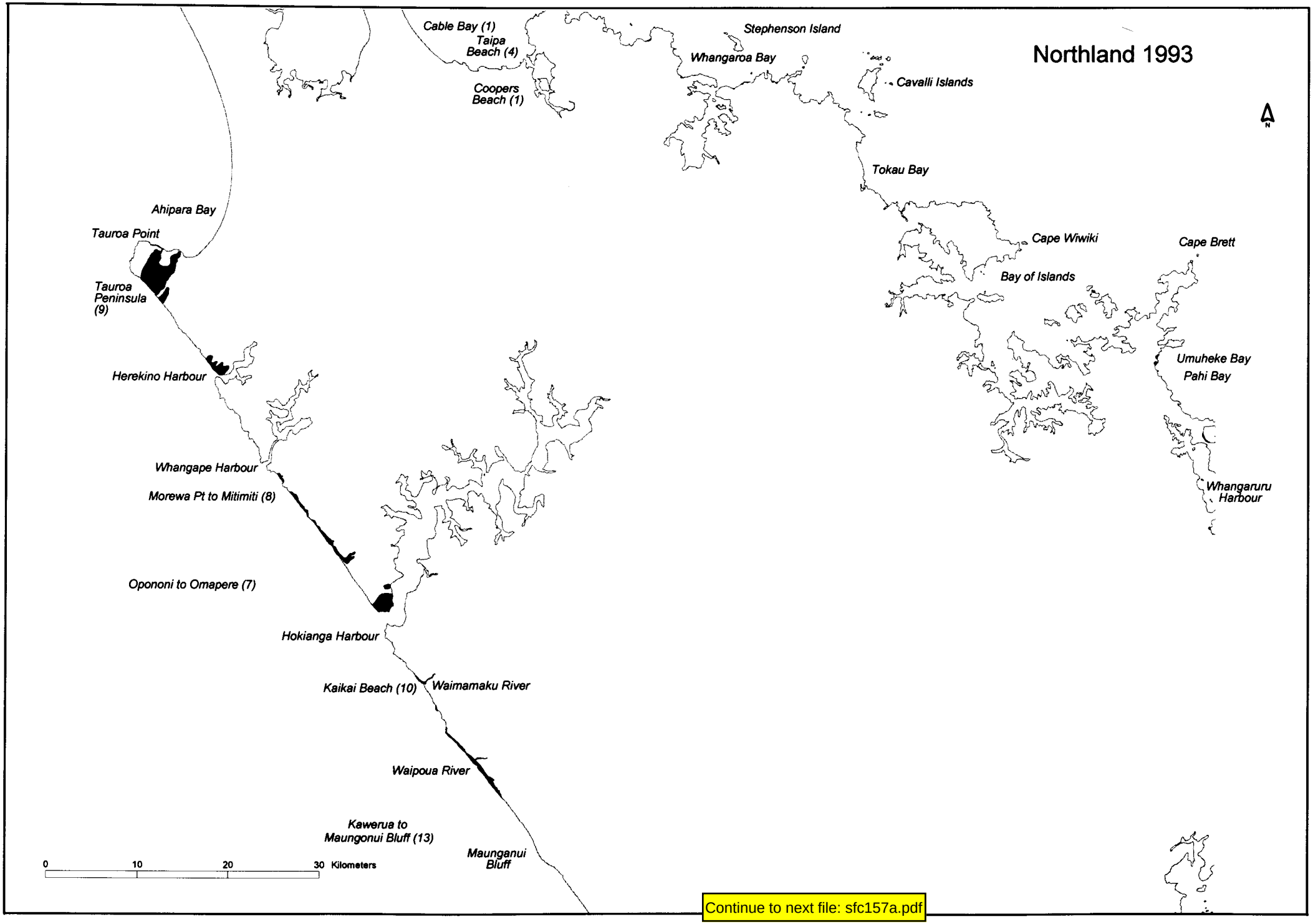

Northland 1993
N
Cape Reinga
Spirits Bay (18)
Tom Bowling Bay (16)
North Cape
Te Werahi Beach (16)
Tapotupotu Bay (9)
Waikuku Beach (16)
Whareana Bay
Twilight Beach (15)
Ponaki Beach
Ngamaru Point (14)
Parengarenga Harbour
Scott Pt to Waikorapupunoa (13)
Kokota Sandspit
Great Exhibition Bay
Taeore to Paxton Pt (17)
The Bluff
Rarawa Beach (14)
Waikoropupunoa - Te Arai (13)
Henderson Bay (13)
Kowhai Beach
Cape Karikari
Te Arai to Waimaharu (12)
Whataru Bay (7)
Karikari Bay (12)
Matai Bay (2)
Rangaunu Bay (13)
Puheke Beach (13)
Ninety Mile Beach
Waimaharu to Aupouri (9)
Kohanga Bay (8)
Tokerau Beach (13)
Berghan Point
Rangaunau Bay
Doubtless Bay
Aupouri to Ahipara (8)
Tauroa Point
Ahipara
0
10
20
30
40 Kilometers

Northland 1957 - 1961




Northland 1993
N
Cape Reinga
North Cape
Parengarenga Harbour
Great Exhibition Bay
The Bluff
Ninety Mile Beach
Cape Karikari
Rangaunu Bay
Doubtless Bay
Berghan Point
Cavalli Islands
Tokau Bay
Tauroa Point
Cape Brett
Herekino Harbour
Whangape Harbour
Whangaruru Harbour
Whananaki Spit
Hokianga Harbour
Kaikai Beach
Ngunguru River
Waipoua River
Whangarei
Manganui Bluff
Omamari Beach
Wairoa River
Bream Bay
Mangawhai River
The Black Rocks
Kaipara Harbour
Kaipara North Head
Area of Duneland 8734.85 ha
Percentage Lost 72.78% from 1957/61
0
20
40
60 Kilometers


Northland 1957 - 1961
Cable Bay (1)
Taipa Beach (4)
Coopers Beach (1)
Stephenson Island
Whangaroa Bay
Cavalli Islands
Tokau Bay
Cape Wiwiki
Cape Brett
Bay of Islands
Umuheke Bay
Pahi Bay
Whangaruru Harbour
Ahipara Bay
Tauroa Point
Tauroa Peninsula (9)
Herekino Harbour
Whangape Harbour
Morewa Pt to Mitimiti (8)
Opononi to Omapere (7)
Hokianga Harbour
Kaikai Beach (10)
Waimamaku River
Waipoua River
Kawerua to Maungonui Bluff (13)
Maunganui Bluff
0 10 20 30 Kilometers



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