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Indigenous terrestrial and wetland ecosystems of Auckland

Auckland Council
Te Kaunihera o Tāmaki Makaurau

Indigenous terrestrial and wetland ecosystems of Auckland

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Edited by Jane Connor.

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This guide is dedicated to John Sawyer whose vision initiated the project and who made a substantial contribution to the publication prior to leaving New Zealand. Sadly, John passed away in 2015.

John was passionate about biodiversity conservation and brought huge energy and determination to the projects he was involved with. He was generous with his time, knowledge and support for his many friends and colleagues.

INDIGENOUS TERRESTRIAL AND WETLAND ECOSYSTEMS OF AUCKLAND

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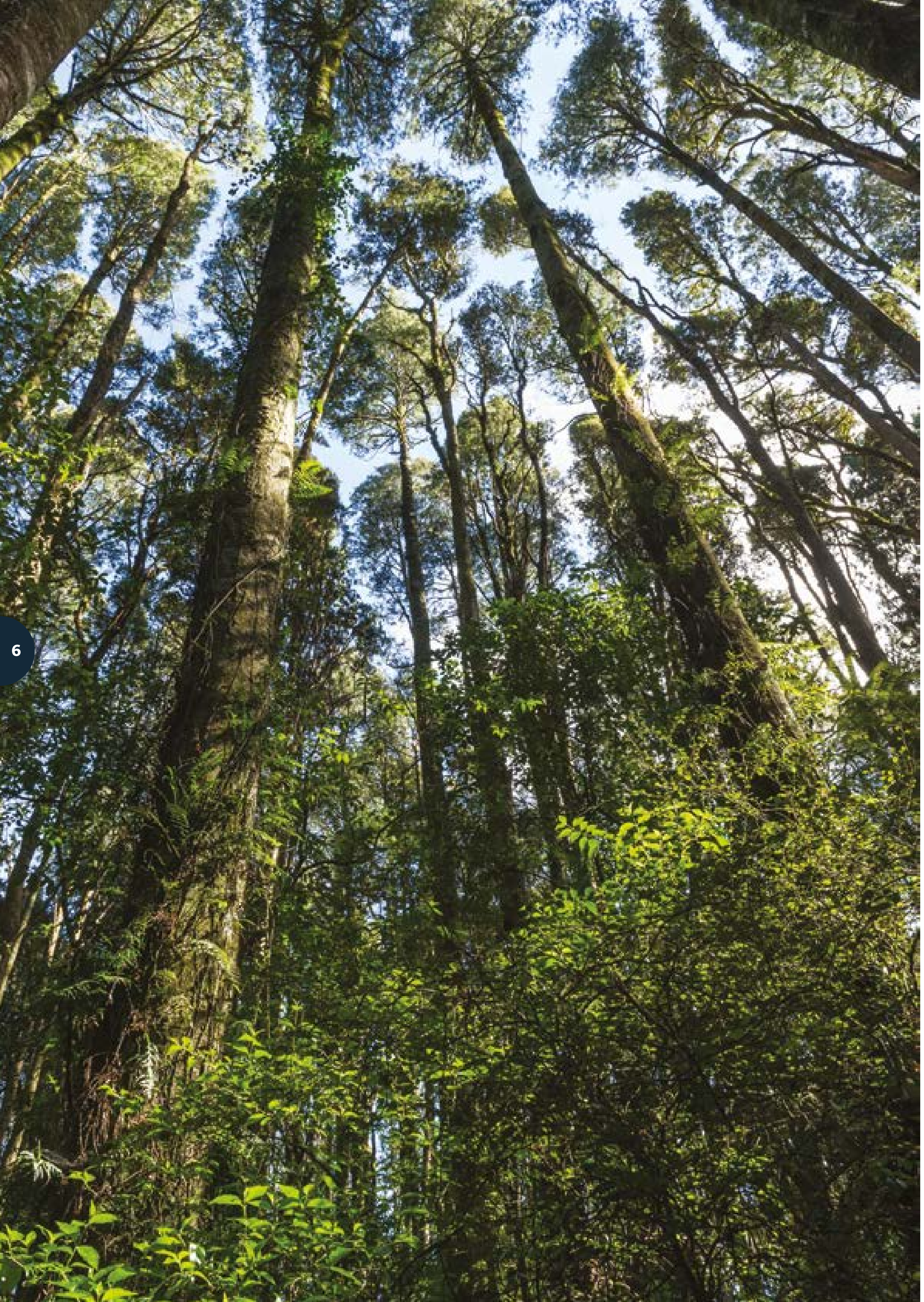


Introduction

This guide describes the 36 terrestrial and wetland ecosystems, and their regional variants, that have been identified by Auckland Council as occurring in the Auckland region. The work is based on the national ecosystem classification system developed by the Department of Conservation (Singers & Rogers 2014). This same classification system was used as the basis for the Department of Conservation's Natural Heritage Management System. It was adopted by Auckland Council so that its programme would complement the work of the Department of Conservation. Waikato, Bay of Plenty, Gisborne, Taranaki and Wellington regional authorities have also classified their region's terrestrial and wetland ecosystems using Singers and Rogers (2014).

In simple terms, an ecosystem is a biological community of interacting organisms and their physical environment. As defined by Keith *et al.* (2013), ecosystems are units of assessment that represent complexes of organisms and their associated physical environment within an area. They have four essential elements:

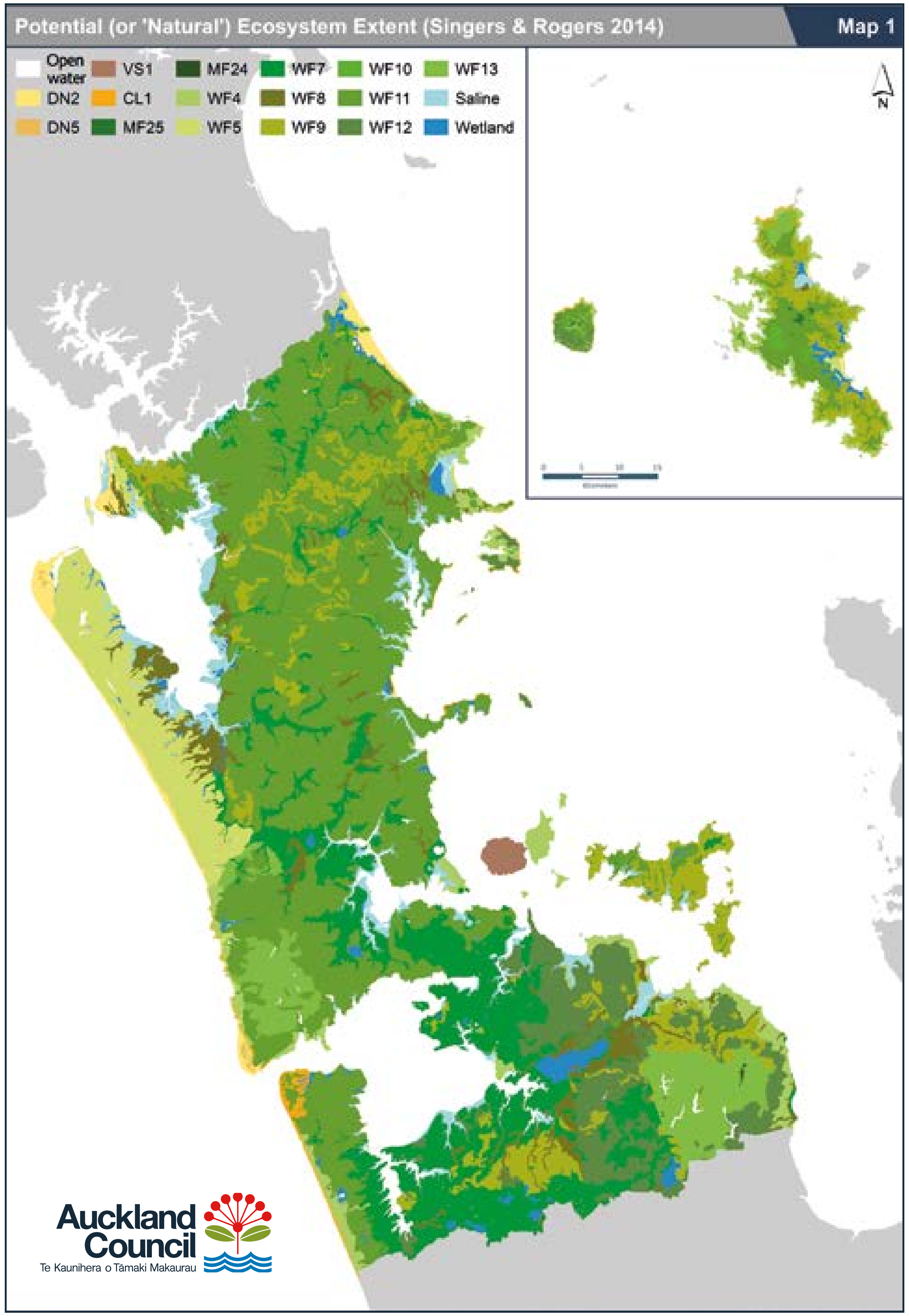
1. a biotic complex or assemblage of species
2. an associated abiotic environment or complex
3. the interactions within and between those complexes
4. a physical space in which these operate.

Ecosystems are defined by a degree of uniqueness in composition and processes (involving the biota and the environment) and a spatial boundary. In this regard they are synonymous with 'ecological communities', 'habitats', 'biotopes' and 'vegetation types'. Ecosystems may vary in size from small ephemeral wetlands to large tracts of forest.

Understanding the regional diversity, distribution and status of ecosystems in the Auckland region has important implications for the protection and enhancement of biological diversity, informing ecological restoration and for state-of-the-environment reporting. Information about which ecosystems occur in the Auckland region, where they are found and their condition, can be used to determine priorities for biodiversity and biosecurity management. It can also inform land-use decisions.

Map 1 shows the natural extent of indigenous terrestrial and wetland ecosystems in Auckland. 'Natural extent' means a combination of our understanding of pre-human diversity, distribution and extent of ecosystems in the Auckland region and what we would expect this to be, given past and current environmental influences. The map shows how the former vegetation of Auckland was dominated by distinct, location-specific forest types. Coastal forests differed from inland kauri, podocarp, broadleaved forests and they differed from kahikatea forests on flood-prone alluvial river terraces. The region also had a variety of non-forest vegetation on sand dunes and in wetlands, which were particularly diverse. Although it is difficult to reconstruct the original extent and variety of wetlands in the region, they were far more widespread than they are now. Map 2 shows the current extent of indigenous terrestrial and wetland ecosystems in Auckland.

Image left: Kahikatea forest near Clevedon. **Jason Hosking.**


Potential (or 'Natural') Ecosystem Extent (Singers & Rogers 2014)
Map 1
Open water
VS1
MF24
WF7
WF10
WF13
DN2
CL1
WF4
WF8
WF11
Saline
DN5
MF25
WF5
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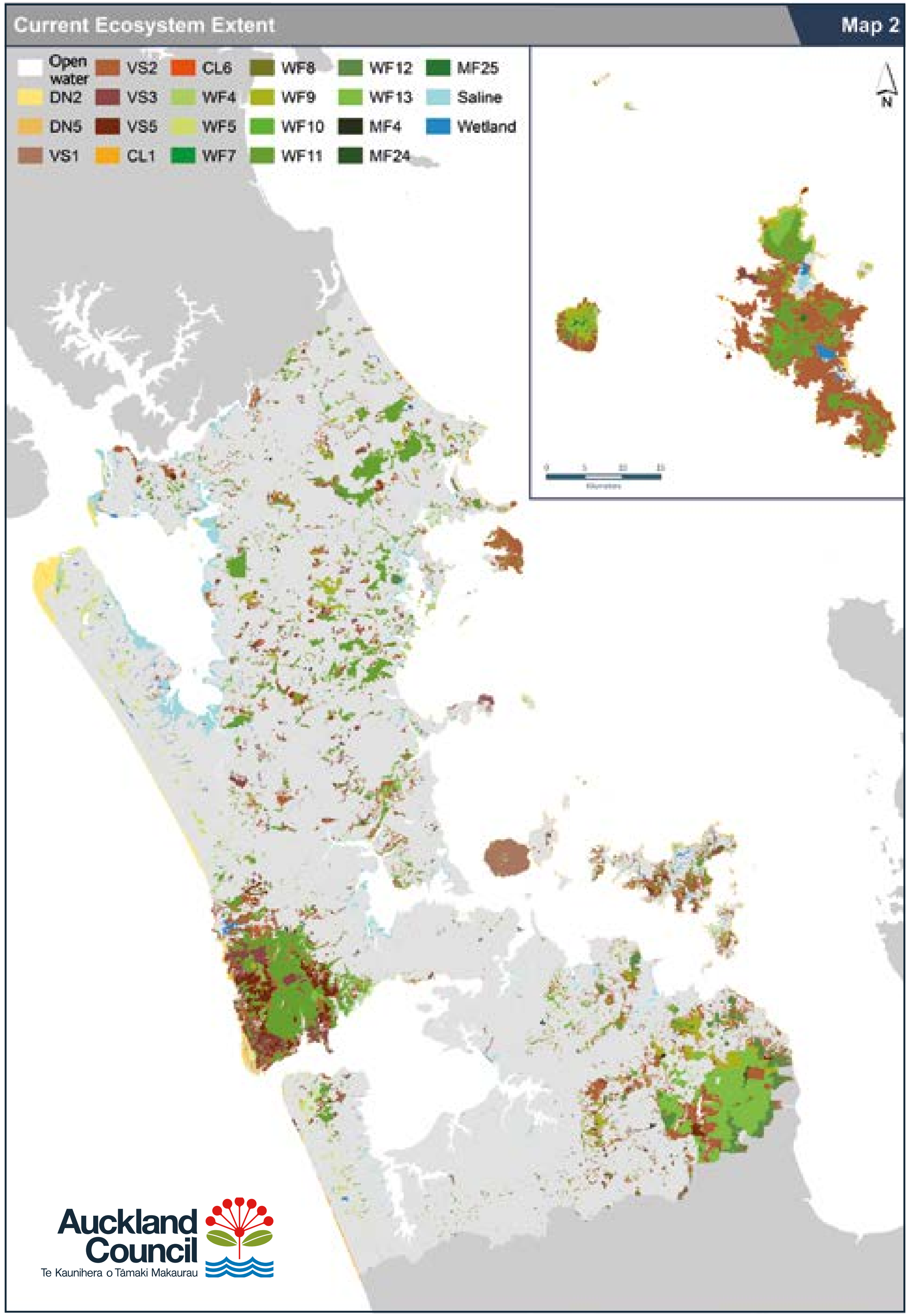
Current Ecosystem Extent
Map 2
Open water
VS2
CL6
WF8
WF12
MF25
DN2
VS3
WF4
WF9
WF13
Saline
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WF5
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Origins of a national ecosystem classification system

The Department of Conservation's national ecosystem classification system (Singers & Rogers 2014) was developed to assist the Department with prioritising ecosystem conservation. This is a fundamental requirement for implementing Goal 3 of the New Zealand Biodiversity Strategy (Department of Conservation and Ministry for the Environment 2000) to: 'maintain and restore a full range of remaining habitats and ecosystems'.

The classification system amalgamates many previous, largely vegetation-based classification systems and a wide range of other ecological studies where no suitable classification existed, aligned with an environmental framework. It draws heavily on Geoff Park's conceptual thinking to describe ecosystems (Park 2000), forest classifications for the North and South Islands (Nicholls 1976; McKelvey 1984), Peter Wardle's *Vegetation of New Zealand* (Wardle 1991) and descriptions of New Zealand's historically rare ecosystems (Williams *et al.* 2007).

The national classification system describes the full range of indigenous ecosystem types that occur in New Zealand on a variety of scales. The ecosystem descriptions within this book are a subset of that national classification. In most cases the descriptions are generalised so that they apply nationwide, though many have been adapted and expanded to describe the character of these within the Auckland region.

It is important to note that not all sites in the Auckland region support the full species composition described under the 'Characteristic native biota' headings. Regional variability, past disturbance or management may mean that some species are not present at a site. Therefore, some sites in Auckland may be classified as an ecosystem for which the description is not an exact match. In other cases, where human influence has caused irreversible environmental change or non-native species have invaded, or both, sites may support novel or hybrid ecosystems.

Mapping Auckland's ecosystems

Over the last few hundred years there have been significant changes to the structure, composition and function of the indigenous terrestrial and wetland ecosystems of Auckland. There has also been a reduction in the natural extent of most ecosystems.

The process of mapping the current extent of Auckland's terrestrial and wetland ecosystems has involved collating data and information from a variety of sources. For example, all terrestrial ecosystem data from past ecological surveys, held by the former councils that now make up Auckland Council, were aggregated and numerous publications documenting the state of indigenous vegetation in Auckland were collated, including the Department of Conservation's Protected Natural Area programme survey reports and research papers for sites throughout the region. Further ecological surveys were carried out for approximately 2000 sites to fill knowledge gaps and to update some of the existing data. The resulting data were used to inform the mapping of ecosystems.

A significant challenge in mapping the current extent of ecosystems was determining the most appropriate classification for ecosystems that had been named using different conventions during previous surveys. Across all of these Auckland ecological datasets, approximately 1000 different names had been used to categorise the Auckland region's ecosystems and each had to be re-catalogued using the new Department of Conservation ecosystem classification. For example, some ecosystems had been named using Atkinson's vegetation classification system (Atkinson 1985a); others had been named without reference to a standard approach. This re-cataloguing was done using species composition and abiotic factors to determine the most appropriate match for each ecosystem.

With this data compiled into one geospatial layer and matched to the current ecosystem classification, it was then possible to determine the current spatial extent of all terrestrial and wetland ecosystems in the Auckland region. Auckland Council will continue to refine the current ecosystem layer as new survey work occurs.

The historic extent of each ecosystem type was mapped by examining modelled historic vegetation spatial datasets. These included the Land Environments of New Zealand dataset (Leathwick *et al.* 2003) and the 'pre-people' layer in Lindsay *et al.* (2009). Categories were directly matched where possible. For ecosystem types where direct matching was not possible, climate, geography, geology and soil characteristics were used as determinants.

For ecosystem types where environmental parameters are less specific, current-extent maps were used, and the associated geographical, geological and soil drivers for the sites mapped as a particular ecosystem type were used to extrapolate across the landscape. Historic mapping was cross-referenced with written accounts of original vegetation cover in Protected Natural Area Programme reports and other ecological district-wide survey reports. Historic mapping compiled for Awhitu and Mānukau ecological districts by Landcare Research in 2000 was also used (Emmett *et al*. 2000).

Threatened ecosystems

Ecosystems around the world are facing transformation as a result of human-induced modification and environmental change (such as climate change). These pose unprecedented threats to biodiversity and the benefits that living organisms and their habitats provide to humanity, including clean water and stable environments for agriculture and fisheries. This threat to ecosystem structure, function and composition has been identified as one of the world's most significant conservation challenges.

The development and application of an improved system to understand and evaluate risks to the world's ecosystems will enable better informed decisions to be made about sustainable environmental management and biodiversity protection.

The International Union for the Conservation of Nature (IUCN) has recently developed a system for assessing the status of ecosystems (Keith *et al.* 2013), applicable at local, regional, national and global levels. It evaluates the severity and impact of multiple symptoms of risk produced by different processes of ecosystem degradation, including changes in the distribution and extent of an ecosystem, degradation of the physical environment and changes to its characteristic species, all of which contribute to risk of decline. The IUCN system allows all these symptoms to be assessed in a standardised way across different ecosystem types and will be of value to a number of different sectors (see Box 1).

Threatened ecosystem assessments in Auckland

The Auckland region, like the rest of New Zealand, is part of a terrestrial biodiversity hotspot

Box 1: Benefits of the IUCN threat assessment of ecosystems

Conservation: to help prioritise actions such as ecosystem protection, restoration and influencing land use practices, and as a means to reward good and improved ecosystem management.

Land-use planning: to highlight the risks faced by ecosystems and ecosystem services as important components of land-use planning, for example, clean water, maintenance of soil fertility, pollination and natural products.

Improvement of governance and livelihoods: to link ecosystem services and livelihoods, and explore how appropriate governance arrangements can improve ecosystem management and livelihood security.

Macro-economic planners: to provide a globally accepted standard that will enable planners to evaluate the risk and related economic costs of losing ecosystem services and, conversely, the potential economic benefits of improved management.

(IUCN 2016)

(see Myers *et al.* 2000) with a diverse range of ecosystem types and associated species. It is widely recognised, however, that indigenous biodiversity in the Auckland region is under threat from continued loss and fragmentation of indigenous land cover, ongoing impact and increasing threat of invasive species and diseases, overharvesting, pollution and climate change (Auckland Regional Council 2010). Many ecosystem types in the Auckland region are thought to have been reduced from pre-human times to less than 10 per cent of their original extent, and others are considered to have been naturally uncommon. To identify which of the region's ecosystems are threatened and to help with prioritising protection, management and restoration, a thorough threatened ecosystem risk assessment was completed.

This report lists the regional conservation status of all of the region's 36 terrestrial and wetland ecosystem types and their regional variants, using the IUCN Red List of Ecosystems criteria (described above) (Keith *et al*. 2013; Bland *et al*. 2016). The criteria include eight categories of risk for each ecosystem (Fig. 1). Three categories are assigned on the basis of quantitative thresholds: Critically Endangered (CR), Endangered (EN) and Vulnerable (VU); together, these categories are described as Threatened. They are complemented by several qualitative categories that accommodate ecosystems that are not threatened comprising:

1. Those that almost meet the criteria for Vulnerable (NT, Near Threatened), or unambiguously meet none of the quantitative criteria (LC, Least Concern). When evaluating the threat classification for Auckland's terrestrial and wetland ecosystems, the NT and LC categories were not differentiated separately. They were collectively classified as Not Threatened.
2. Ecosystems for which too little data exists to apply any criterion (DD, Data Deficient).
3. Ecosystems that have not yet been assessed (NE, Not Evaluated).

An additional category (CO, Collapse) is assigned to ecosystems that have collapsed throughout their distribution, the equivalent of the extinct category for species.

To conduct the assessments, ecological survey data and maps were collated and classified by ecosystem type.

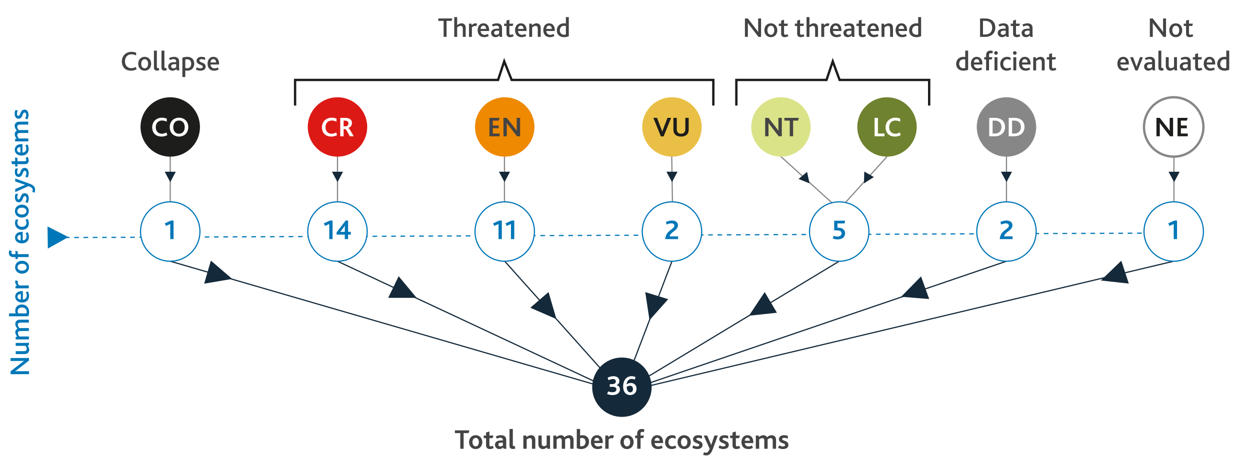
The following were then determined or inferred for each ecosystem type using a combination of geographical (GIS) mapping and workshops held with experts:

- rates of decline in ecosystem distribution (using historic and current extent calculations)
- restricted geographic distribution with continuing declines or threats (anticipated increased risk of stochastic effects with fewer sites occupied)
- rates of environmental (abiotic) degradation (e.g. wetland drainage)
- rates of disruption to biotic processes or interactions (e.g. pest plant and animal impacts).

IUCN threat assessments for the Auckland region's terrestrial and wetland ecosystems are shown in Fig. 1.

The extensive historical clearance of indigenous vegetation has contributed to almost 40 per cent of the Auckland region's terrestrial and wetland ecosystems being identified as Critically Endangered.

Fig. 1: Threat categories for ecosystems in the Auckland region (after Bland *et al.* 2016).



In ecosystems where there has been less clearance, the presence of threats such as animal pests, weeds, drought and drainage have resulted in many more ecosystems being assessed as Threatened (either Critically Endangered, Endangered or Vulnerable). On a more positive note however, our assessment process showed that it was clear that active management by agencies and landowners in the region had improved or prevented further decline in the threat status of several ecosystems.

Introduction to the ecosystem descriptions

This guide includes descriptions of all of the terrestrial and wetland ecosystems of the Auckland region. There are nine sections representing the main ecosystem categories (forest, cliff, regenerating, wetland, coastal saline, dune, geothermal, cave and anthropogenic). The introduction to each section provides an overview and is followed by detailed descriptions of each ecosystem, including information about its abiotic processes, national and Auckland regional distribution (and examples of sites in the region), characteristic native flora and fauna, key processes and interactions, and threats.

Ecosystem unit code abbreviations are: WF, warm forests; MF, mild forests; WL, wetlands; DN, active coastal sand dunes; CL, cliffs; SA, saline; GT, geothermal; CV, cave; and VS, vegetation succession (regenerating ecosystems).

The threat status of each ecosystem is given at the start of the description. These assessments provide vital insights into the state of Auckland's terrestrial and wetland ecosystems, guidance for statutory protection, and will help to prioritise active conservation management.

Photographs are included of each ecosystem along with examples of its significant flora and fauna. For some of the main ecosystem types, we have recognised variants that reflect a greater level of diversity; for these, additional information is provided about their structure and composition. The appendices contain a summary of ecosystem types in the Auckland region and glossaries of flora and fauna names. The flora glossary shows the ecosystem types in which the various plant species occur.

Variable oystercatcher. **Geoff Moon.**

Forest ecosystems

Most forest ecosystems in the Auckland region are fragmented as a result of human modification and disturbance. Successional and regenerating forest remnants now occur within a landscape of predominantly urban and rural land uses. Despite this, many of Auckland's forests have retained high levels of diversity and species richness. This complexity is the result of a combination of biotic and abiotic factors, and it is assisted by ongoing management efforts.

Out of 59 forest ecosystems identified nationally, 12 forest ecosystems occur in the Auckland region. These include broadleaved forest ecosystems in coastal areas, montane and cloud forests in the Hunua and Waitākere Ranges and on Little and Great Barrier Islands, and pūriri forests on alluvial and volcanic soils, among others.

All of the Auckland region's forest ecosystems are threatened to varying degrees. These include swamp and flood-plain kahikatea forests (WF8, MF4), pūriri forest (WF7) and much of the Auckland region's kauri forest (WF10). Very few natural dune-forest ecosystems remain (less than 1 per cent across the entire range), with the largest remnants occurring on the west coast sand country from Āwhitu through to South Kaipara. Some forest ecosystems are naturally range-restricted, such as the montane podocarp forest (MF25) on rare, seabird-burrowed soils near the summit of Little Barrier Island.

A notable feature of tawa, broadleaved, podocarp forest ecosystems (WF13) is the *Weinmannia* gap in the vicinity of Auckland, where both kāmahi (*Weinmannia racemosa*) and tōwai (*W. silvicola*) are absent (McKelvey & Nicholls 1959). The northern extent for kāmahi is the Hunua Ranges and Manukau Harbour, while the southern extent for tōwai is the northern Waitākere Ranges.

It is likely that occasional severe droughts on Auckland's free-draining basaltic soils, contribute to this distribution gap.

Many of the threats to the long-term viability of forest ecosystems in the Auckland region are similar to those seen elsewhere in New Zealand. These include habitat destruction, fragmentation, edge effects and invasion by pest plants. Pest animals cause serious damage to forests through browsing and seed predation, and stock cause damage through browsing and trampling. Mammalian predators also significantly reduce populations of native fauna, many of which are important pollinators and seed dispersers in our native forests.

Some of the localised threats to forests in the Auckland region include rural and urban development, soil erosion (in the regenerating dune forests), and the spread of the invasive pathogen *Phytophthora agathidicida* (commonly known as PTA) in kauri forests. Kauri dieback is now emerging as a serious threat to kauri and the kauri forest ecosystem (Jamieson *et al.* 2014). In Auckland, the Hunua Ranges contain the largest stands of kauri forest that remain free of kauri dieback.

Image left: Tawa, kohekohe, rewarewa, hīnau, podocarp forest (WF13) in the Hunua Ranges. **Jason Hosking.**

WF4

Pōhutukawa, pūriri, broadleaved forest

[Coastal broadleaved forest]

Regional IUCN threat status: Endangered

This coastal broadleaved forest ecosystem occurs in parts of the coastal zone exposed to winds and salt spray, predominantly within 600–800m of the shore; though extending further inland in exposed locations, on larger inshore islands and on recent volcanic surfaces. It is found on a wide range of landforms and soils of moderate fertility, including allophanic, brown, granular, recent and ultic soils (Molloy 1998).

Distribution: In frost-free areas from the Three Kings Islands and Te Paki south to Mahia and New Plymouth, with outliers around some central North Island lakes. The southern boundary conforms with the southern limits of pūriri, aligning approximately to the thermic soil temperature zone (Molloy 1998). In the Auckland region, although much reduced from its original extent, remnants of this forest type are scattered along the coastline, with some of the best examples in coastal parts of the Waitākere Ranges and on Great Barrier Island.

Characteristic native flora: Broadleaved species dominate this forest, with pōhutukawa, pūriri and kohekohe most common and, locally, taraire, karaka, tawa, tītoki, mangeao, rewarewa, puka, tawāpou, ngaio and nīkau. Kauri, kōwhai species, pōhutukawa and kānuka may be present on dry ridges as well as locally, tānekaha and hard beech (McKelvey & Nicholls 1959; Nicholls 1976; Esler 1983; Conning 2001). On some northern offshore islands, especially the Three Kings, there are local endemic species and varieties.

Auckland's remaining examples are often dominated by pōhutukawa, pūriri and taraire. In some places taraire almost completely dominates the forest canopy. Sheltered coastal locations within estuaries or the upper reaches of harbours are often less dominated by pōhutukawa, with pūriri, kōwhai and kohekohe more common. Seabirds are a feature, though they are now largely restricted to predator-free islands. On fresh volcanic surfaces at Rangitoto Island, younger successional variants (VS1), currently dominated by pōhutukawa, are developing slowly towards this ecosystem type.

Characteristic native fauna:
Pre-human era: Pōhutukawa, pūriri, broadleaved forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Forest productivity would have been enhanced by the nutrients brought ashore by burrowing and surface-nesting seabirds (Atkinson & Millener 1991; Smith *et al.* 2011). On the mainland, several species of forest moa would have browsed leaves and twigs and eaten fallen fruits, while nectar-feeding reptiles and birds would have benefited from an almost year-round food supply (Whitaker 1987; Clout & Hay 1989; Kelly *et al.* 2010). Adzebill and brown and little spotted kiwi were probably present, along with forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). Large-fruited trees, such as pūriri, karaka, tawa, taraire, tawāpou and kohekohe, would have attracted frugivorous species, such as kākāpō, kākā, kererū, huia, saddleback, kōkako and piopio. Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

Present: These forests are an important habitat for kererū, which may rely on good quantities of fruit to breed (Pierce & Graham 1995), while geckos, kākā, tūī and bellbird take abundant nectar in season (Whitaker 1987; Clout & Hay 1989; Anderson 2003; Kelly *et al.* 2010). Pōhutukawa, pūriri, broadleaved forests support the more common native bush birds, e.g. morepork, kingfisher, shining cuckoo, fantail, grey warbler, tūī and silvereye. Others, such as kākā, kākāriki species, long-tailed cuckoo, rifleman, whitehead, robin, tomtit, hihi, bellbird, saddleback and kōkako, still occur only on larger pest-free

A large coastal forest remnant on the Maungatauhoro headland between Wenderholm beach and Waiwera River. **Alastair Jamieson.**

The saddleback/tieke thrives in pest-free coastal forests where there are plenty of natural nesting and roosting cavities and where its favoured foods, invertebrates, fruits and nectar are plentiful. **Martin Sanders.**

islands or within some mainland sanctuaries.
Tree cavities in species such as pūriri and pōhutukawa, in places free of mammalian predators, provide shelter, roosting and nesting sites for geckos, kākā, kākāriki, hihi, saddleback and bats. Introduced birds include rosella, dunnock, blackbird and chaffinch.

Key processes and interactions: This ecosystem is largely dependent on a warm coastal climate. Most dominant species (e.g. pūriri and kohekohe) have shade-tolerant seedlings and readily regenerate beneath the forest canopy. Others (e.g. pōhutukawa), require high light conditions and regeneration is prompted by disturbance.

Most canopy species rely on birds for pollination and/or seed dispersal. Before human settlement, nesting seabirds would have been a common component of the ecosystem and would have been important for enhancing soil fertility, productivity and regeneration (Bellingham *et al.* 2010).

Threats: This type of forest was severely reduced in extent by human settlement, first Māori and later European, with a large proportion burnt and cleared for agriculture or timber. Many remaining examples are small and continue to suffer through fragmentation. On the mainland, there are a few examples with high ecological integrity, while others are reverting to something like their former composition (e.g. Waitākere coast). The best remaining examples occur on the northern offshore islands, many of which are managed nature reserves free of mammalian pests.

Animal pests and a wide range of weeds are significant threats. Many common canopy species (e.g. pōhutukawa and kohekohe) are highly palatable to possums and ungulates. High numbers of pests can result in canopy collapse and dominant species such as pūriri, pōhutukawa and kohekohe may fail to regenerate. Predators, especially rats, can be very abundant and they have decimated or eliminated some invertebrate, reptile and bird species.
The proximity of remaining examples to settlements means that invasive weeds are diverse and common, although the dense structure of intact examples of this ecosystem can provide some resistance to weed invasion (Sullivan *et al.* 2005). Often, merely being fragmented and regenerating makes this ecosystem type more vulnerable to weed invasion. As with other coastal ecosystems in the Auckland region, sea level rise resulting from anthropogenic climate change may threaten this ecosystem with increased erosion and possible inundation.

Coastal pōhutukawa forest at Karekare. **Jason Hosking.**

Coastal forest on the shores of Okura estuary. **Jason Hosking.**

WF5

Tōtara, kānuka, broadleaved forest

[Dune forest]

Regional IUCN threat status: Critically Endangered

This rare and threatened ecosystem occurs in frost-free areas on stabilised dunes. Soils are derived from coastal sands from a wide range of rock types and soil fertility is generally low. Soils range from very recent Holocene coastal sands to relatively young Pleistocene sands with a higher (10–20 per cent) clay content (Molloy 1998). All soils are free-draining, however more-recent examples are excessively so and are vulnerable to drought, especially on dune-ridge crests. This type includes the nationally rare ecosystem 'Stable sand dunes' (Williams *et al.* 2007).

There are two regional variants of this ecosystem type:

- WF5.1: Kānuka on dunes (early successional).
- WF5.2: Podocarp–broadleaved forest on dunes (includes pōhutukawa-dominated forest and mixed tōtara-broadleaved forest).

Regional variants of dune forest would have had variations in species composition. Large dunelands (e.g. North and South Kaipara Heads), being older and with more diverse landforms, probably had a greater range of dune-forest communities compared with simple coastal dune ridges (e.g. eastern Coromandel beaches).

Distribution: From North Cape to Kawhia, Coromandel, Matakana Island and Bay of Plenty coast to East Cape. In the Auckland region, originally widespread on stabilised dunes of the South Head and Āwhitu peninsulas, Te Arai to Pakiri, and in parts of Tapora. Now reduced to small remnants in these areas.

Characteristic native flora: Very few examples of the original dune forest remain; most examples are seral and are dominated by kānuka scrub. This ecosystem description is therefore constructed from the few remaining examples in better condition (e.g. Whakapaingarara/Tapu Bush and Pretty Bush near Pouto) and supported by the findings of Ogle (1997), and Smale *et al.* (1996).

The forest would have been a mosaic of communities, with changes in composition reflecting the major environmental gradients of age since dune stabilisation, soil development and fertility, and the varied topographical patterns of dunes. Closest to the coastline and further inland on recently stabilised (though formerly transgressive) dunes, kānuka and, locally, pōhutukawa would have been the primary woody colonisers. Later, tōtara and a wide variety of broadleaved trees, including tītoki, māhoe, rewarewa and pōhutukawa, would have established. As soils developed further, more broadleaved tree species would have progressively colonised, including karaka, kohekohe, tawa, pūriri, hīnau and locally, narrow-leaved maire and taraire, finally developing into a coastal broadleaved forest type. On the driest and most exposed dune-ridge crests, kānuka may have persisted in association with other drought-tolerant species (e.g. ngaio, māpou, pōhutukawa and tōtara).

Characteristic native fauna:
Pre-human era: As with other forest types, this coastal duneland forest ecosystem would have supported a diverse range of invertebrates, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002), especially in those places where more mature broadleaved trees existed in the later successional stages. Forest productivity would have been enhanced by the nutrients brought ashore by burrowing and surface-nesting seabirds (Atkinson & Millener 1991; Smith *et al.* 2011). Several species of moa, adzebill, takahē and New Zealand raven were probably also present, along with little blue penguin, brown and little spotted kiwi, weka, forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013).

The drier, younger forest stages dominated by kānuka might have had fewer large frugivores, such as kererū and kōkako, but a higher proportion of insectivorous birds, such as wrens, fernbird, whitehead, tomtit, robin, fantail, grey warbler, saddleback and piopio, while honeydew from kānuka would have attracted hihi, bellbird and tūī.

Geckos would have been abundant in the kānuka forest, and they would have fed on invertebrates as well as kānuka honeydew and seasonal nectar sources such as pōhutukawa, and also taken fruits from various small-fruited shrubs and trees (Whitaker 1987).

In prehuman times Mantell's moa was common in open coastal habitats. © **Te Papa. Artist: Paul Martinson.**

Present: The tiny remnants of these forests support a few species of the more-common native bush birds, e.g. morepork, kingfisher, shining cuckoo, fantail, grey warbler, tūī and silvereye, and small numbers of geckos. Introduced birds include pheasant, brown and California quail, rosella, dunnock, blackbird, song thrush and chaffinch.

Key processes and interactions: This ecosystem occupies the warm climatic zone on stabilised coastal dunes of predominantly Holocene age, grading into early Pleistocene on the largest dunelands (e.g. North and South Kaipara Heads).

The free-draining soils are drought-prone, making the ecosystem highly vulnerable to fire.

Threats: This ecosystem is now very rare and threatened, with less than 1 per cent remaining across its entire (national) range, largely due to pre-European fires and the resulting soil erosion and dune mobility. Extant examples consist of small fragments dominated by kānuka and other seral vegetation (Smale 1994), and only a few remaining examples of older podocarp-broadleaved forest. Key threats include pests (possums and locally, feral fallow deer and horses), weeds, coastal land development, sand encroachment from mobile dunes, and edge effects from adjoining land uses (e.g. agriculture and forestry).

Image top: Tōtara, kānuka, broadleaved forest [dune forest] (WF5) on the shores of Lake Rototoa. **Jason Hosking.**

Below: Lake Rototoa at South Kaipara Peninsula, with dune forest in foreground. **Alastair Jamieson.**

WF7 Pūriri forest

Regional IUCN threat status: Critically Endangered

This variable ecosystem occurs on the northern North Island's most fertile soils of alluvial and volcanic origin within the warm climatic zone.

Three variants occur, determined primarily by landform and soil type:

- WF7.1: On alluvial terraces with recent free-draining (often stony) soils (Wardle 1991).
- WF7.2: On basalt volcanoes – younger volcanoes have skeletal soils on lava, although fertile granular soils develop in depressions, on ash and tuff, and with time (e.g. Papakauri soil). Occurs on the volcanic fields in three main areas: Pukekohe–Auckland, Whangārei and Kerikeri–Kaikohe (Conning 2001; mapped in Molloy 1998).
- WF7.3: on alluvial terraces on recent fluvial (silt) soils derived primarily from mudstones and siltstones, including central Northland, western Waikato and on the East Coast (e.g. Greys Bush near Gisborne) (Clarkson & Clarkson 1991). Historically occurred in low-lying areas adjacent to the Kaipara and Manukau harbours (Auckland Regional Council 2004).

Distribution: In predominantly frost-free, warm and sub-humid areas from Northland to northern Waikato, Bay of Plenty and Poverty Bay.

In the Auckland region, this forest ecosystem was originally widespread on alluvial terraces and on the volcanic soils of the isthmus, but is now reduced to small, scattered remnants. Examples of WF7.2 occur at Withiel Thomas Reserve in Mt Eden and Sylvan Park Reserve at Lake Pupuke.

Characteristic native flora: Broadleaved forest with abundant pūriri, and composition corresponding to the variants above as follows:

- WF7.1: Pūriri with occasional tōtara, mataī, kahikatea and tītoki, locally with kōwhai and taraire.

Pūriri flowers. **John Braggins.**

- WF7.2: Mixed broadleaved forest typically dominated by pūriri, karaka, kohekohe and, locally, taraire and kohekohe. Also present are occasional tōtara, mataī, pukatea, rewarewa, tawa, tītoki and northern rātā, and locally, abundant nīkau. Composition is strongly related to landform and soil development. On more exposed lava with skeletal soils, mangeao, tītoki, karaka, māhoe, houpara and occasional pūriri occur, colloquially referred to as 'rock forest' (Smale & Gardner 1999). Secondary successional examples are often dominated by māhoe, puka, akeake and rangiora; having an abundance of puka and akeake they still maintain some character of 'rock forest'.
- WF7.3: Pūriri with occasional kahikatea, kohekohe and nīkau.

Secondary successions are often dominated by podocarp trees, with tōtara and kahikatea most abundant, especially in Auckland and Northland.

Characteristic native fauna:

Pre-human era: Pūriri forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). In some places, forest productivity would have been enhanced by the nutrients brought ashore by burrowing and surface-nesting seabirds (Atkinson & Millener 1991; Smith *et al.* 2011). Several species of moa, adzebill, brown and little spotted kiwi were probably present, along with forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). Abundant fruit and nectar would have favoured species such as kākāpō, kākā, kererū, huia, saddleback, kōkako and piopio (Clout & Hay 1989; Atkinson & Millener 1991), while nectivorous reptiles and birds would have benefited from an almost year-round nectar supply (Whitaker 1987; Kelly *et al.* 2010). Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Large cavities in pūriri would have provided shelter, roosting and nesting sites for geckos, kākā, kākāriki, hihi, huia, saddleback and bats.

Present: These forests provide fruit and nectar for kererū and tūī (Clout & Hay 1989; Anderson 2003; Kelly *et al.* 2010), and habitat for the more common native bush birds, e.g. morepork, kingfisher, shining cuckoo, fantail, grey warbler and silvereye. Introduced birds include rosella, blackbird, chaffinch, starling and myna. Tree cavities in species such as pūriri and pōhutukawa in places free of mammalian predators provide shelter, roosting and nesting sites for geckos, kākā, kākāriki, hihi, saddleback and bats.

Rare pūriri forest on basalt lava (WF7.2) at Withiel Thomas Reserve, Mt Eden. **Jason Hosking.**

Key processes and interactions:
Our understanding of the composition of this forest temporally and spatially with respect to landform and soil variation is lacking, because only fragments remain. Mixed pūriri-dominant broadleaved forest occurs on alluvial and marine terraces, typically with well-drained to imperfectly-drained fertile to moderately fertile soils in warm areas of New Zealand. It also occurs on recent basaltic volcanoes, or neighbouring land, where ash fall has significantly increased fertility.

The seedlings of pūriri and other broadleaved trees are shade-tolerant, so are capable of regenerating beneath existing relatively closed canopy forest and consequently, podocarp trees are infrequent. Pūriri is very long-lived and may dominate over hundreds to thousands of years.

Vegetation succession on recent volcanic lava fields during the warm Holocene period has initially been dominated by *Metrosideros* forest (including the pōhutukawa/northern rātā and hybrids of VS1), e.g. the contemporary forest on Rangitoto Island (Clarkson 1990). Over several thousand years, forest diversity increases with soil development, especially on tuff, ash and scoria landforms. Eventually, a mixed broadleaved forest dominates, within which pūriri, kohekohe, karaka, mangeao and tītoki are common. Forest succession was likely to have been more complex, with intermediate stages where species such as mangeao, rewarewa and tītoki dominated for periods of time or in specific situations, such as on drier lava flows and relicts of 'rock forest' on Mt Eden (Esler 1991, Smale & Gardner 1999). Taraire is more abundant on older and more weathered basalt soils such as on the Kaikohe volcanic field (Conning & Miller 1999). This suggests that as soils age, and weather and fertility declines, there is a gradual replacement of pūriri with taraire as the dominant species.

Threats: As this ecosystem occurs on highly fertile soils, it was greatly reduced in extent especially by Māori and European land clearing for horticulture and agriculture (Esler 1991).

Remaining examples are small and highly fragmented, and suffer from edge effects, weed invasion and locally, stock grazing. Pest mammals, especially possums and rats, are also significant threats, depleting palatable species and eating fruits and seeds, as well as preying on vulnerable fauna, including pollinators and seed dispersers.

Canopy species composition has probably been altered through selective logging of highly sought after podocarp and pūriri trees. This has resulted in limited recruitment and preferential replacement by species such as taraire, tawa and kohekohe (Shanks 2011).

Image left: Pūriri Forest. **Jason Hosking.**

Below: Mature forests provide an abundance of food for kākā along with numerous tree cavities where they can nest. **Simon Fordham / NaturePix.**

WF8 Kahikatea, pukatea forest

Regional IUCN threat status: Critically Endangered

Omaha swamp forest interior. **Jason Hosking.**

This ecosystem is essentially a swamp forest growing on soils with seasonally high water tables.

Distribution: Predominantly in the west of the North Island from Northland to Wellington (e.g. western Egmont National Park), on poor-draining alluvial, organic and gley soils in warm to mild and humid to sub-humid areas; also localised areas in Nelson and Blenheim to the southern limit of pukatea and swamp maire. In the east in semi-arid regions, it is restricted to small areas in permanent wet depressions and lake margins (e.g. Lake Ponui, southern Wairarapa).

It is found throughout the Auckland region where frosts are minimal, but is heavily reduced in its former extent and now restricted to small remnants.

The swamp forest at Omaha Taniko Wetlands Scientific Reserve on the Whangateau Harbour is one of the best remaining examples.

Characteristic native flora: This ecosystem is dominated by podocarp–broadleaved forest, with emergent trees or a canopy of kahikatea and pukatea, and locally, rimu. Swamp maire occurs in areas with a high water table (Johnson & Brooke 1989), and tawa, māhoe and locally, tītoki on areas of drier ground (Smale 1984). Kiekie, whekī and supplejack are often abundant, creating a dense structure and sub-canopy. In northern New Zealand, taraire and kohekohe also occur on drier ground (McKelvey & Nicholls 1959). Characteristic forest-floor species include mapere, swamp astelia, parataniwha and kiokio. Many fragments have had kahikatea harvested from them and are often now dominated by a forest of pukatea, swamp maire, kiekie and supplejack, although this species composition is not common in the Auckland region.

Characteristic native fauna:
Pre-human era: Kahikatea, pukatea forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Several species of moa, adzebill, brown and little spotted kiwi were probably present, along with forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). In some years the mast fruiting of kahikatea would have provided an abundant food source for kākāpō, kākā, kākāriki, kererū, tūī, bellbird, huia, saddleback, kōkako and piopio, along with the larger gecko species (Whitaker 1987; Clout & Hay 1989; Kelly *et al.* 2010). Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Large rotted-out cavities in emergent pukatea would have provided nesting and roosting sites for kākā, kākāriki, hihi, huia, saddleback and bats.

Present: Mast-fruiting kahikatea are favoured by kererū and tūī, but are also exploited by some introduced birds, such as rosella and blackbird.

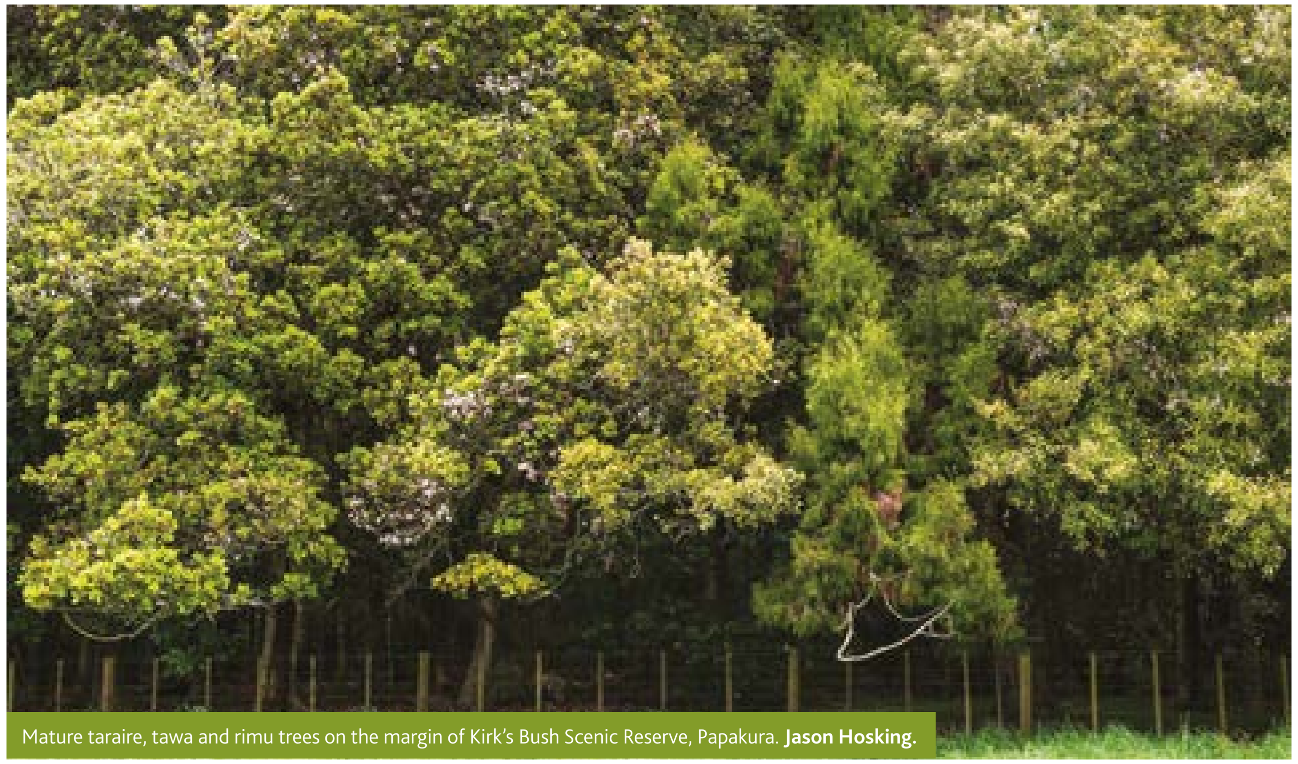
Omaha swamp forest with Whangateau Harbour saltmarsh in the foreground. **Jason Hosking.**

In addition to these species, kahikatea, pukatea forest supports the usual range of native bush birds, such as morepork, kingfisher, shining cuckoo, fantail, grey warbler and silvereye.

Key processes and interactions:
Primarily dependent on a high water table and limited by drought, this ecosystem occurred on landforms (e.g. depressions) or in humid climates where these conditions prevailed. Kahikatea and swamp maire have bird-dispersed fruits, and these forests would have been seasonally significant food sources for many species (e.g. tūī and kererū).

Threats: This forest type has been greatly reduced in extent through drainage and with land development for agriculture. Most examples are now small or highly fragmented. The largest examples in the best condition (with intact hydrology) occur on public conservation land in Taranaki, in western Egmont National Park, Mokau Scenic Reserve and Hutiwai Conservation Area, though the former has had most of the kahikatea removed (Clarkson 1986). Most of the other extant examples have also suffered from lowered water tables as a result of land drainage, allowing invasion or replacement by species more suited to drier habitats. Their dense structure and wet soils mean the impact of weeds and stock is often limited to the margins, though introduced ground-covers (e.g. tradescantia and African clubmoss) readily invade.

WF9 Taraire, tawa, podocarp forest



Mature taraire, tawa and rimu trees on the margin of Kirk's Bush Scenic Reserve, Papakura. **Jason Hosking.**

Regional IUCN threat status: Endangered

This ecosystem type occurs on moderately fertile soils (including brown, granular and recent) and is almost exclusively associated with andesitic and basaltic parent materials (McKelvey & Nicholls 1959). The topography where it occurs is variable, with shallow to steep hill-slopes interspersed with ridges. Species composition is strongly related to landform and moisture availability, and is variable between gullies, hill-slopes and ridges.

Distribution: In predominantly frost-free areas below 450m, from the lower Waikato district northwards, throughout Northland and on Great Barrier Island where kauri is absent (McKelvey & Nicholls 1959). Found throughout the Auckland region with some of the best and most extensive examples remaining in the Hunua Ranges. Kirk's Bush in Papakura is a small, but easily accessible example of this ecosystem type.

Characteristic native flora: Three major variants of this forest type occur, of which two are minor in extent (McKelvey & Nicholls 1959). The most common and extensive variant (WF9.1) is characterised by large emergent rimu and northern rātā, with kahikatea in gullies emerging over a broadleaved canopy of abundant taraire and kohekohe, with tōwai and tawa becoming more common at higher altitudes. Other associated species include occasional hīnau, rewarewa and pukatea, and locally, miro, pūriri and karaka in lowland areas. In the sub-canopy, nīkau and tree ferns (especially mamaku) are locally abundant. On ridges, rimu, miro, rewarewa and mangeao are dominant, while pukatea is most numerous in gullies.

In Northland and Coromandel, a second, uncommon variant (WF9.2) occurs at higher altitude in humid locations, on poor-draining soils on plateaux and hill-crests. Taraire, swamp maire and tāwari are often co-dominant with occasional wind-swept rimu and kahikatea, while lowland species such as pūriri and karaka are absent.

A third variant (WF9.3) occurs from north of Warkworth (Omaha Forest) south to the Hunua Ranges in the '*Weinmannia* gap', where both tōwai and kāmahi are absent. In this variant, taraire is less

Kereru can swallow large fruits and are important seed dispersers for pūriri, taraire, tawa and tawāpou. **Jason Hosking.**

abundant, while kohekohe, rewarewa, pūriri, tawa and hīnau are comparatively more common (Barton 1972).

Characteristic native fauna:
Pre-human era: As with other forest ecosystems, taraire, tawa, podocarp forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Forest productivity would have been enhanced by the nutrients brought ashore by burrowing seabirds (Atkinson & Millener 1991; Smith *et al.* 2011). Several species of moa, adzebill and brown and little spotted kiwi were probably present, along with forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). Large fruiting rimu could have been a trigger for kākāpō breeding in these forests in the past (Harper *et al.* 2006), and abundant taraire, tawa and kohekohe would have supported good populations of kererū and kōkako. Flowering kohekohe would have attracted large numbers of hihi, tūī and bellbird in early winter. Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

Present: Taraire, tawa, podocarp forests in the Hunua Ranges support the last natural kōkako population in the Auckland region, along with relict populations of New Zealand falcon, kākā, bellbird and long-tailed bat. The tomtit is also numerous. This forest type supports the usual range of other native bush birds, such as morepork, kingfisher, shining cuckoo, fantail, grey warbler, tui and silvereye. Very few introduced birds penetrate far into the larger native forests; those that do include rosella, blackbird, chaffinch and myna. Hochstetter's frogs are common in the numerous small streams, but lizards are scarce.

Key processes and interactions: The most important factor influencing the composition of this forest is the variable landforms it occupies. Native birds, especially kererū and tūī, are important for the pollination and seed dispersal of a wide range of canopy and sub-canopy species.

Threats: As it occurred on moderately fertile soils, most of this forest type on easy slopes was cleared for agriculture, and it is now largely restricted to steep lands, such as the Hunua Ranges. Many remaining areas have been logged for podocarps, especially rimu and kahikatea (Nicholls 1976), and in these forests taraire has increased in abundance. Animal pests are significant threats, with possums, goats and rats especially, causing the decline of palatable flora and vulnerable fauna. In combination, possums and goats have the potential to cause mortality and regeneration failure of palatable canopy and sub-canopy species (Payton 2000). Intact, closed canopy examples are relatively resistant to weed invasion, though shade-tolerant ground covers (e.g. tradescantia, African clubmoss and wild ginger) and trees and shrubs (e.g. monkey apple, tree privet and bangalow palm) readily invade.

WF10 Kauri forest

Regional IUCN threat status: Endangered

This iconic northern forest occurs in predominantly warm and sub-humid–humid areas with rainfall 1000–2500 mm, on hill-slopes and hill-crests, especially on more moderate slopes, on ultic or oxidic soils grading to podzols that are often seasonally waterlogged (Ecroyd 1982; Molloy 1998). Kauri forms a deep mor-type humus with a pH of approximately 4.2, which promotes leaching and results in declining soil fertility over time, as part of the nutrient pool is sequestered into the unavailable organic fraction (Ecroyd 1982; Meurk 1995; Burns & Leathwick 1996). Kauri is long-lived, and wind-throw with associated soil disturbance caused by subtropical cyclones influences forest regeneration and soil rejuvenation cycles (Ecroyd 1982; Wardle 1991; Meurk 1995). Without these cyclonic disturbance events, there is evidence to suggest soils become so severely leached and podzolised (especially when combined with fire) that they are no longer capable of supporting forest. Instead, a fire–induced community dominated by mānuka, tangle fern and sedges prevails; this is colloquially known as gumland (Meurk 1995; Clarkson *et al.* 2011) (see WL1).

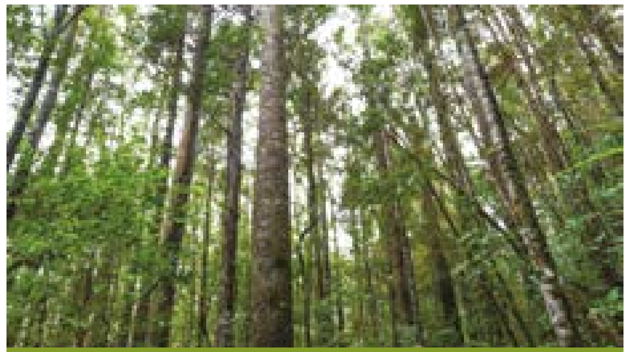
There are two WF10 Kauri forest variants:

- WF10.1: Mature kauri forest
- WF10.2: Regenerating kauri 'ricker' stands.

Distribution: In Northland, Auckland and Coromandel. Now largely restricted to western Auckland, Northland hill country (e.g. Warawara and Waipoua Forests), and stands on Great Barrier Island, and in the Waitākere and Hunua Ranges.

Characteristic native flora: Dense stocking of large kauri, often of a similar size, forming a near-complete monotypic canopy.

Sub-canopy trees mostly have trunks of small diameter and commonly include occasional podocarp (miro, rimu, toatoa, thin-barked tōtara, tōtara, tānekaha and, locally, monoao) and broadleaved



Kauri ricker forest in Okura Scenic Reserve. **Jason Hosking.**

trees (rātā, tawa, taraire, hīnau, rewarewa, kohekohe and tōwai). Regional variation occurs, for example tōwai is absent from the Waitākere Ranges. Characteristic sub-canopy species include toru, needle-leaved neinei, kiekie, *Gahnia* spp. and kauri grass (McKelvey & Nicholls 1959; Nicholls 1976; Ecroyd 1982).

Regenerating kauri forests are present throughout Northland, Auckland and Coromandel, generally replacing mānuka and kānuka scrub on land that was previously burnt. These forests tend to have a high stocking of young kauri, often in association with tānekaha, occasional tōtara, rimu, rewarewa and in coastal locations, pōhutukawa. The ground layer is generally sparse owing to the density of the canopy trees. In areas where kauri seed sources have been lost, tānekaha is often dominant.

Characteristic native fauna:
Pre-human era: Pure stands of kauri forest, because it has fewer nectar and fruit sources, possibly supported a less diverse range of fauna compared with podocarp and podocarp–broadleaved forest types. Kauri seed, however, might have been a trigger in northern forests for kākāpō breeding (Harper *et al.* 2006), and was probably also an important seasonal food source for kākā. On higher ridges there could have been localised petrel colonies, which would have provided additional nutrients to otherwise heavily leached, poor soils (Atkinson & Millener 1991; Smith *et al.* 2011). Moa, adzebill and brown and little spotted kiwi were probably present, along with forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). In disturbed or burned areas of kauri gumland, mānuka, tangle fern and sedges would have provided habitat for fernbird.

Present: Kauri forests support the usual more-common native bird species, such as morepork, kingfisher, shining cuckoo, fantail, grey warbler and silvereye, with kererū and tūī less common than in mixed broadleaf forest types. Introduced species, such as white cockatoo, rosella, blackbird, chaffinch and myna, are also present.

Key processes and interactions:
The major factors influencing the composition of this ecosystem are soil fertility, altitude and geographic location (Burns & Leathwick 1996; Ecroyd 1982). Over millennia, cyclical disturbances caused by subtropical storms are required to facilitate the regeneration of kauri (Wardle 1991).

Threats: Kauri forests are one of the few New Zealand mature forest types prone to fire and there is evidence that significant areas were burnt by Māori and Europeans. Fire resulted in loss of nutrients and, on soils with the lowest natural fertility, induced gumland vegetation (Esler & Rumball 1975; Clarkson *et al.* 2011). During the kauri gum boom, many kauri trees were bled, resulting in fungal invasion and subsequent rot.

Kauri is generally unpalatable to pest mammals, although they can browse associated palatable flora, particularly the broadleaved component. Closed-canopy mature kauri forests are generally highly resistant to weed invasion. Many kauri forests are suffering from kauri dieback, caused by the invasive pathogen *Phytophthora agathidicida* (commonly known as PTA). Kauri dieback is now emerging as a serious threat to the species and wider ecosystem (Jamieson *et al.* 2014). In the Auckland region, the Hunua Ranges and Little Barrier Island contain the largest stands of kauri forest that remain free of kauri dieback.

Image top right: Kauri ricker forest. **Alastair Jamieson.**

Understorey in kauri ricker forest, Okura Scenic Reserve. **Jason Hosking.**

Kauri cone. **John Sawyer.**

WF11 Kauri, podocarp, broadleaved forest

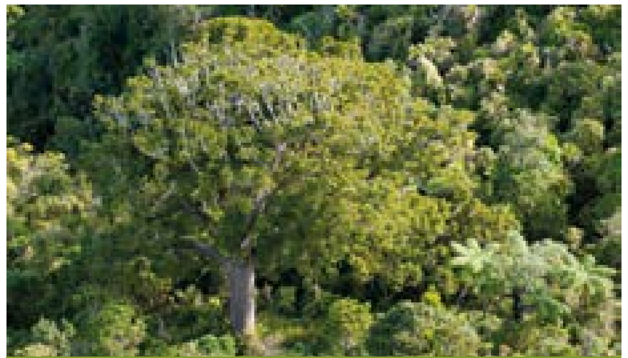
Regional IUCN threat status: Endangered

This diverse forest ecosystem is commonly derived from logged kauri forest, occurring in warm and sub-humid–humid areas with rainfall 1000–2500mm. It is found predominantly on hill-slopes with acidic leached soils (oxidic, ultic soils grading to podzols) where kauri occurs; more fertile (granular) soils have broadleaved species in gullies (Molloy 1998). Where kauri and podocarp trees are present, soil fertility is in decline, especially on more stable sites (Burns & Leathwick 1996). Canopy species can be long-lived, and wind-throw and associated soil disturbance caused by subtropical cyclones are significant factors influencing forest regeneration and soil rejuvenation cycles (Wardle 1991; Meurk 1995).

Distribution: Northern North Island, from north of Hamilton and Tauranga to North Cape, including Great Barrier and Little Barrier Islands. Predominantly from near sea level to 350m, and up to 500–600m on the Coromandel Peninsula, Great Barrier and Little Barrier islands. There are also good examples of this ecosystem type in the Waitākere Ranges, Rodney District and on the North Shore.

Image top left: Kauri, podocarp, broadleaved forest in the Cascades Kauri Park, Waitākere Ranges. **Alastair Jamieson.**

Characteristic native flora: A diverse forest related to topographical and edaphic factors, with a wide range of canopy and sub-canopy species. Kauri predominantly (but not exclusively) occurs on ridge-crests and hill-slopes, with broadleaved species more abundant in gullies. Podocarp trees are widespread, with rimu, tōtara, thin-barked tōtara, miro and tānekaha more common on ridges, while kahikatea is more common in gullies and on alluvial terraces. Broadleaved trees are often dominant in gullies, and include taraire, tawa, tōwai, kohekohe, pūriri, northern rātā, pukatea and rewarewa. Altitudinal variants occur, with taraire and kohekohe locally more abundant at lower altitude, while tawa and tōwai are more abundant at higher altitudes (McKelvey & Nicholls 1959; Nicholls 1976; Esler 1983; Burns & Leathwick 1996). Tōwai is locally absent from most of the Auckland region (McKelvey & Nicholls 1959).



Large kauri are often emergent in the canopy of the kauri, podocarp, broadleaved forest ecosystem. **Alastair Jamieson.**

Characteristic native fauna:

Pre-human era: Kauri, podocarp, broadleaved forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Forest productivity would have been enhanced by the nutrients brought ashore by burrowing seabirds (Atkinson & Millener 1991; Smith *et al.* 2011).

Kauri, podocarp, broadleaved forest is widely distributed throughout the Waitākere Ranges including the upper Karamatura valley. **Alastair Jamieson.**

Several species of moa, adzebill, brown and little spotted kiwi were probably present, along with forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). Large-fruited trees, such as pūriri, tawa, taraire and kohekohe, would have attracted species such as kākāpō, kākā, kererū, saddleback, huia, kōkako and piopio. Moa, in addition to browsing leaves and twigs, would have eaten fallen fruits, while nectivorous reptiles and birds would have had an almost year-round nectar supply (Whitaker 1987; Clout & Hay 1989; Kelly *et al.* 2010).

Miro. **John Sawyer.**

Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

Present: These forests are an important habitat for kererū, which usually need good quantities of fruit to breed (Pierce & Graham 1995), while geckos, kākā, tūī and bellbird take abundant nectar in season (Whitaker 1987; Clout & Hay 1989; Anderson 2003; Kelly *et al.* 2010). Kauri, podocarp, broadleaved forests support the more common native bush birds, e.g. morepork, kingfisher, shining cuckoo, fantail, grey warbler, tūī and silvereye, with others such as kākāriki species, long-tailed cuckoo, rifleman, whitehead, robin, tomtit, hihi, bellbird, saddleback and kōkako on larger pest-free islands. Tree cavities in species such as pūriri and pōhutukawa in places free of mammalian predators provide shelter, roosting and nesting sites for geckos, kākā, kākāriki, hihi, saddleback and bats.

Introduced species, such as white cockatoo, rosella, blackbird, chaffinch and myna, are also present.

Key processes and interactions: The major factors influencing the composition of this forest are fertility, drainage and altitude (Burns & Leathwick 1996). Over millennia, cyclical subtropical storm-induced disturbance is required to facilitate the regeneration of many canopy species, especially kauri and podocarps (Wardle 1991). Native birds, particularly kererū and tūī, are important for the pollination and seed dispersal of a wide range of canopy and sub-canopy species (Clout & Hay 1989).

Threats: Significant human-induced modification from both Māori and European settlement has occurred. Remaining areas have mostly been heavily logged, especially for kauri and podocarp trees, and many extant examples have also been burnt (Conning 2001). Pest mammals are significant threats, with possums, goats and rats especially causing the decline of palatable flora (Payton 2000) and vulnerable fauna (Innes *et al.* 2010). Possums and goats in combination have the potential to cause canopy collapse and regeneration failure of a wide range of species within this ecosystem.

Closed-canopy intact examples are highly resistant to weed invasion, though shade-tolerant ground-covers (e.g. tradescantia, African clubmoss and wild ginger) and trees and shrubs (e.g. monkey apple, privet and palms) readily invade. Many kauri forests are suffering from kauri dieback, caused by the invasive pathogen *Phytophthora agathidicida* (commonly known as PTA). Kauri dieback is now an emerging serious threat to the species and wider ecosystem (Jamieson *et al.* 2014). In the Auckland region, the Hunua Ranges and Little Barrier Island contain the largest stands of kauri forest that remain free of kauri dieback.

WF12 Kauri, podocarp, broadleaved, beech forest

Regional IUCN threat status: Endangered

This forest type occurs in warm and sub-humid areas, generally below 600m, in a mild and humid climate. Soils are of low to moderate fertility, derived generally from weathered parent materials that include greywacke, argillite, dacite and rhyolite. It occurs almost exclusively on hill-slopes that are often of a steep gradient, and in the Hunua Ranges it is more common on south-facing slopes (Barton 1972).

Distribution:
Occurs predominantly in eastern areas south of Auckland, from the Hunua Ranges to Hapuakohe Ecological District in the Waikato region. It is also present on Mt Taupiri, the Coromandel Range and Hauraki Gulf islands (e.g. Waiheke and Little Barrier). On Mt Te Aroha (Kaimai Range), it rises to 600m. It was likely once more common in eastern Northland and Coromandel, however it is now comparatively rare (McKelvey & Nicholls 1959; Wardle 1984; Collins & Burns 2001). On the Auckland mainland it occurs most predominantly in the Hunua Ranges with pockets elsewhere including the North Shore. Hard beech is present as occasional trees in forests in Rodney, but not in sufficient quantity for it to be described as this (WF12) ecosystem type.

Characteristic native flora:
Hard beech, occasional tānekaha, thin-barked tōtara and kauri are generally confined to ridges. In gullies and on shallow hill-slopes, rimu, miro, tawa, hīnau, northern rātā, rewarewa, and locally, kohekohe, narrow-leaved maire and tāwari occur (Nicholls 1976; Wardle 1984).

Characteristic native fauna:
Pre-human era: Kauri, podocarp, broadleaved beech forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

Kauri, podocarp, broadleaved, beech forest on Hauturu/Little Barrier Island. **Tim Lovegrove.**

The whitehead was formerly common in many North Island mainland forest ecosystems. **Tim Lovegrove.**

In some places, forest productivity would have been enhanced by the nutrients brought ashore by burrowing seabirds (Atkinson & Millener 1991; Smith *et al.* 2011). Several species of moa, adzebill, brown and little spotted kiwi were probably present, along with forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991, Worthy & Holdaway 2002, Holdaway *et al.* 2013). Kauri, podocarps and hard beech could have been triggers in northern forests for kākāpō breeding (Harper *et al.* 2006), and kauri seed was probably also an important seasonal food source for kākā. Fruiting podocarps and tawa on the lower slopes and in gullies would have attracted species such as kākāpō, kākā, kererū, huia, saddleback, kōkako and piopio (Clout & Hay 1989; Kelly *et al.* 2010). Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

Present: These forests support the more common native bush birds, e.g. morepork, kingfisher, shining cuckoo, fantail, grey warbler, tūī and silvereye, with others such as kākāriki species, long-tailed cuckoo, rifleman, whitehead, robin, tomtit, hihi, bellbird, saddleback and kōkako on larger pest-free islands. Introduced birds include rosella, blackbird, chaffinch and myna. Tree cavities in old beech trees in places free of mammalian predators provide shelter, roosting and nesting sites for geckos, kākā, kākāriki, rifleman, hihi, saddleback and bats.

Key processes and interactions: The major factors that influence the composition and structure of this forest type are the age of the landforms it occupies and the associated repeating ridge–gully landforms, which create variable soil fertility and moisture deficits. The resulting forest pattern is a mosaic. Ridges and steep, drought-prone hill-slopes with shallow and infertile soils are occupied by hard beech, kauri and tānekaha. Shallow hill-slopes and gullies with more moist, fertile soils are occupied by broadleaved and podocarp trees.

Threats: This forest type has been reduced in extent throughout its range. However, the degree of loss is difficult to determine because significant areas of the suitable land on the eastern side of Northland, Auckland and the Coromandel Peninsula are now deforested. Much of this occurred before European colonisation. Wardle (1984) considered that it was likely to have been more common on the Coromandel Peninsula based on Thomas Kirk's observations around the Thames goldfields, where hard beech was a prominent species in 1869, though by 1889 all stands had been destroyed (Wardle 1984).

Most remaining areas occur on public conservation land or other reserves, although many are largely secondary and modified by fire and logging. The greatest threat to the forest structure and composition is from pest animals, such as goats, possums and rats, browsing on palatable flora (Payton 2000) and preying on vulnerable fauna (Innes *et al.* 2010).

Closed-canopy intact examples are highly resistant to weed invasion, though shade-tolerant introduced ground-covers (e.g. tradescantia, African clubmoss and wild ginger) and trees and shrubs (e.g. monkey apple and palms) readily invade. Many kauri forests are suffering from kauri dieback, caused by the invasive pathogen *Phytophthora agathidicida* (commonly known as PTA). Kauri dieback is now an emerging serious threat to the species and wider ecosystem (Jamieson *et al.* 2014). In the Auckland region, the Hunua Ranges and Little Barrier Island contain the largest stands of kauri forest that remain free of kauri dieback.

A North Shore kauri, podocarp, broadleaved beech remnant. **Jason Hosking.**

WF13 Tawa, kohekohe, rewarewa, hīnau, podocarp forest

Regional IUCN threat status: Vulnerable

This broadleaved–podocarp forest type occurs across a wide geographic area and altitudinal range, in warm and sub-humid to humid climates, on a wide range of moderately fertile soil types, including allophanic, brown, pumice and recent soils (Knowles & Beveridge 1982).

Distribution: Inland hill country and higher ground where kauri is absent, from Northland to the Waitākere, Hunua and Coromandel Ranges; in Northland it occurs on ranges above taraire's altitudinal limit, from 450–550m. From the Hunua Ranges into the Waikato and Bay of Plenty regions, it is the dominant forest type, often occurring inland from pōhutukawa, pūriri, broadleaved forest (WF4), on shallow to steep hill-slopes and gullies 150–550m above sea level. It is more widespread throughout the lowlands of the Waikato and Bay of Plenty regions, southwards to New Plymouth in the west and Mahia Peninsula in the east.

Characteristic native flora: Tawa and kohekohe are the most abundant canopy species. There are several regional variants with many co-occurring trees. Rimu, northern rātā, miro and kahikatea are the most common emergent trees, while hīnau, rewarewa and pukatea are often present in the canopy, locally with mangeao. Kāmahi or tōwai, pūriri and nīkau also occur locally at lower altitudes. Tōwai is locally absent in parts of the Auckland region, while tōtara is more common (McKelvey & Nicholls 1959; Nicholls 1976).

Tawa, kohekohe, rewarewa, hīnau, podocarp forest understorey in the Hunua Ranges. **Jason Hosking.**

Kōkako are now thriving in the extensive tawa, kohekohe, rewarewa, hīnau, podocarp forests of the Hunua Ranges as a result of effective predator control. **Geoff Moon.**

Characteristic native fauna:

Pre-human era: Tawa, kohekohe, rewarewa, hīnau, podocarp forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Forest productivity would have been enhanced in some places by the nutrients brought ashore by burrowing seabirds, such as black, Cook's and mottled petrels (Atkinson & Millener 1991; Smith *et al.* 2011). Several species of moa, adzebill, brown and little spotted kiwi were probably present, along with forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). Fruiting trees such as podocarps, tawa, mangeao and kohekohe would have attracted species such as kākāpō, kākā, kākāriki, kererū, saddleback, huia, kōkako and piopio, while nectar-feeding reptiles and birds would have visited rātā and kohekohe flowers in season (Whitaker 1987; Clout & Hay 1989; Anderson 2003; Kelly *et al.* 2010). Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

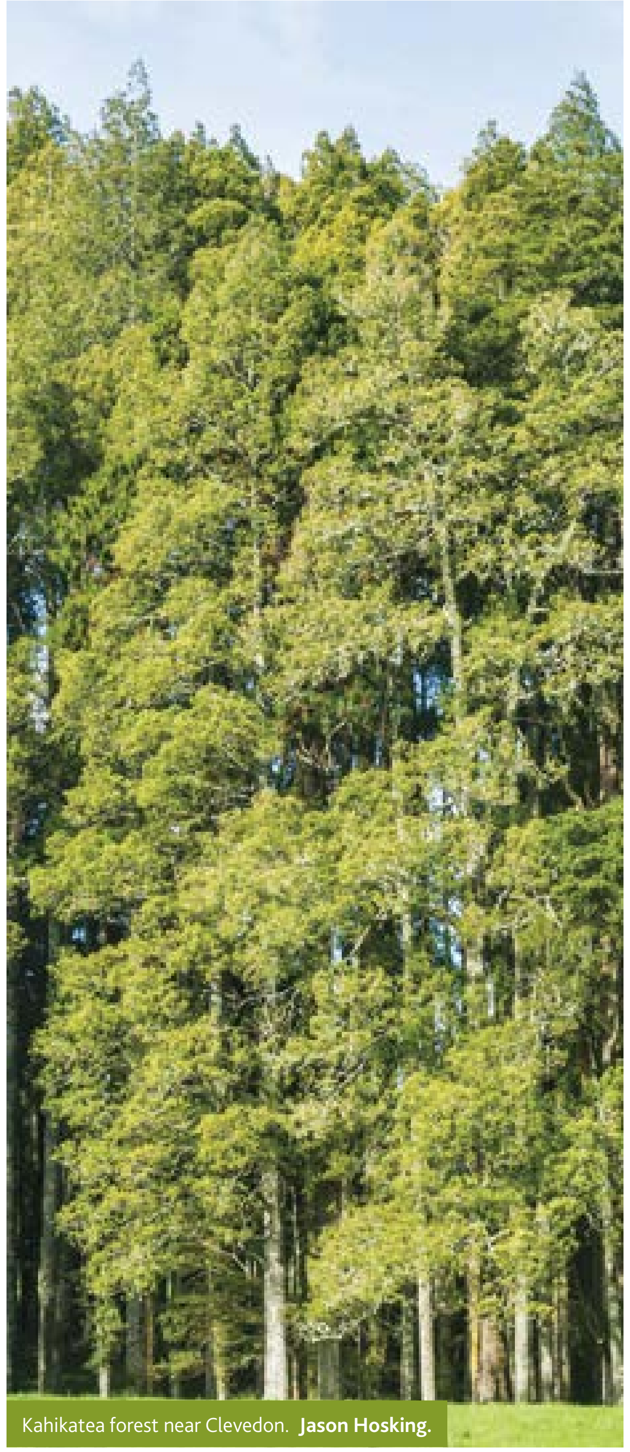
Present: These forests are important habitats for kererū and tūī, and in the Hunua Ranges also have relict New Zealand falcon, kākā, bellbird and kōkako populations. These forests also support the other common native bush birds, e.g. morepork, kingfisher, shining cuckoo, fantail, tomtit, grey warbler and silvereye. Introduced birds include rosella, blackbird and chaffinch. Emergent trees such as kahikatea provide roosts for long-tailed bats, while streams in some areas have populations of Hochstetter's frogs.

Key processes and interactions: Most dominant species within this forest type (e.g. tawa and kohekohe) have shade-tolerant seedlings and readily regenerate in tree-fall canopy gaps. The regeneration of podocarps such as rimu and kahikatea often required periodic major disturbance events such as cyclones. Native birds, especially kererū and tūī, and locally, bellbird and kōkako, are important for the pollination and seed dispersal of a wide range of canopy and sub-canopy species.

Threats: Formerly common on hill-slopes over large areas of the northern North Island, this forest type has been greatly reduced in extent by logging and agricultural land development (Nicholls 1976). Pest animals are significant threats, with possums, goats and rats especially causing the decline of palatable flora (e.g. kohekohe and northern rātā) and vulnerable fauna (e.g. kōkako) (Payton 2000; Innes *et al.* 2010). Possums and goats in combination have the potential to cause canopy collapse and regeneration failure of a wide range of species within this ecosystem. Closed-canopy intact examples are highly resistant to weed invasion, though shade-tolerant introduced ground-covers (e.g.tradescantia, African clubmoss and wild ginger) and trees and shrubs (e.g. privet and bangalow palm) readily invade (Wiser & Allen 2006).

MF4 Kahikatea forest

Regional IUCN threat status: Critically Endangered


Kahikatea forest near Clevedon. **Jason Hosking.**

This ecosystem occurs primarily in sub-humid to semi-arid climatic zones on lowland Holocene flood plains with poor-draining recent (gleyed alluvium), gley and organic soils (Molloy 1998). Rarer examples occur on lake and lagoon margins. These gleyed alluvium and gleyed soils have moderate to high fertility. Flooding occurs periodically and results in extended spells of water-logged soils that are generally dry in summer. Frosts occur regularly on low-lying land.

Distribution: Predominantly eastern North Island and South Island, but including inland in Northland, Waikato, Manawatu and Nelson. In the South Island, the southern limit is near Oamaru (Maxwell *et al.* 1993; Moore 1999; Whaley *et al.* 2001; Holland 2011). Found as small remnants in frost-prone lowland areas in the Auckland region including Coatesville, Kaukapakapa and Clevedon.

Characteristic native flora: The forest is characterised by abundant kahikatea, capable of forming a very tall, near-monotypic canopy. Along streams and rivers where soils are better drained, mataī is present and can be locally co-dominant with kahikatea. Sub-canopy species include ribbonwood, lacebark, kōwhai, tītoki, māhoe, kaikōmako and divaricating shrubs. Local variation occurs with the presence or absence of sub-canopy species, especially ribbonwood, houhere and tītoki. Pukatea is usually present where frosts are light.

In the Auckland region, the understorey typically comprises divaricating shrubs including tūrepo, swamp māhoe, round-leaved coprosma and poataniwha. This ecosystem often intergrades to either non-forest wetland or, on better-drained soils, alluvial forest types containing abundant tōtara, mataī and, locally, tītoki; and in the northern North Island, pūriri (WF7).

Characteristic native fauna: Pre-human era: Kahikatea forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Several species of moa, adzebill, brown and little spotted kiwi were probably present,


Kererū feeding on kahikatea fruit. **Geoff Moon.**

along with forest-inhabiting ducks, raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). The mast fruiting of kahikatea would have provided an abundant food source for kākāpō, kākā, kākāriki, kererū, tūī, bellbird, huia, saddleback, kōkako and piopio, along with the larger gecko species. Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

Present: Masting kahikatea are favoured by kererū and tūī, but are also exploited by some introduced birds such as rosella and blackbird. In addition to these species, kahikatea forest supports the usual range of native bush birds such as morepork, kingfisher, shining cuckoo, fantail, grey warbler and silvereye.

Key processes and interactions: The environmental processes responsible for this ecosystem are primarily a mild climate, periodic frosts, and flooding resulting in periods of inundation and saturated soils. Flooding and silt deposition have formed the floodplains occupied by this ecosystem, resulting in a complex pattern of subtle micro-topography that affects soil structure and drainage. Species which occur in poorly draining areas are in close proximity to species that occupy drier and better-drained ground.

Threats: Much of this ecosystem type survived pre-European fires, even in eastern semi-arid areas (Meurk 2008); the vegetation was less flammable on landforms and soils that rarely experienced drought. European colonisation greatly reduced the extent, as it contained large volumes of valuable timber (e.g. kahikatea), and it occurred on flat land that was highly productive once it was cleared and drained. Virtually all extant examples are small, fragmented and have modified hydrological regimes as a result of being drained; most are surrounded by intensive agriculture. Smale *et al.* (2005) identified three major threats to the long-term integrity of kahikatea fragments: lowering of the water table; increased fertility, especially of phosphates; and weed invasion. Fragmentation has other consequences, including increasing edge effects and incidental damage from surrounding land uses. Lowering of the water table will likely facilitate invasion by a wider range of plant species (both native and introduced) normally occurring in drier forest types (e.g. Gordon Park) (C.C.Ogle pers. comm.). Despite being long recognised as a highly under-represented ecosystem type, many examples remain legally unprotected and grazed by stock.


Kahikatea fruit. **John Braggins.**

MF24 Rimu, tōwai forest

Regional IUCN threat status: Critically Endangered

This ecosystem is restricted to ridges, hill-slopes and plateaux over 450m above sea level that experience high rainfall, frequent cloud cover and wind exposure. It occurs on ranges that were primarily formed by basaltic and andesitic volcanic activity, although in the Auckland region it also occurs on uplifted greywacke of the Hunua Ranges. Over millions of years the topography has been strongly eroded to form steep hill-slopes and locally, summit plateaux. Soils are strongly weathered and clay-rich, and of low fertility (Molloy 1998), though localised areas of podzols occur in depressions on undulating summit plateaux.

Distribution: From the Coromandel and Hunua Ranges northwards to the Herekino and Maungataniwha Ranges south of Kaitaia. Only found in the Auckland region above 450m in the Hunua Ranges, where this forest ecosystem was heavily modified by pest mammals, but is now under conservation management.

Characteristic native flora:
This podocarp–broadleaved forest is characterised by occasional emergent rimu, northern rātā and miro. Tōwai is typically abundant in the canopy, other than near Auckland, where it occurs only occasionally (Barton, 1972). Also occurring are occasional hīnau, rewarewa, tāwari, pukatea and locally, mangeao, raukawa, tāwheowheo and hutu. Swamp maire occasionally occurs along stream courses.

Characteristic native fauna:
Pre-human era: Rimu, tōwai forest would have supported a range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991, Worthy & Holdaway 2002). Forest productivity would have been enhanced by the nutrients brought ashore by burrowing seabirds (Atkinson & Millener 1991, Smith *et al.* 2011), especially black petrels, which often burrow on the higher ridges where there are deep, peaty soils and good take-off points. Where kākāpō were present, as with kauri, tōwai, rātā, montane podocarp forest, summit ridges probably featured the track and bowl systems of this lek-breeding species (Merton *et al.* 1984), with the surrounding vegetation clipped back by the birds. Seasonal nectar sources from rātā species and tāwari would have been used by tūī, bellbird, hihi and geckos, while various shrubs and trees would have been browsed by kākāpō. Insectivores could have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991, Worthy & Holdaway 2002).

Present: In the Hunua Ranges, this ecosystem supports kākā, kererū, tomtit, fantail, grey warbler, silvereye, tūī, bellbird and kōkako. Introduced birds are usually sparse and include blackbird and chaffinch. Although reptiles are scarce, Hochstetter's frogs occur in stream headwaters.

Key processes and interactions: The major factors that influence the composition and structure of this ecosystem type are related to altitude, the landforms it occupies and soil drainage. The forest pattern is a mosaic related to topography, with kamahi and tōwai being the most abundant canopy trees outside the Auckland region, especially on steep ridges and hill-slopes, often co-occurring with occasional rewarewa and hīnau. Shallow hill-slopes and gullies with deeper soils of higher fertility are occupied by tawa, mangeao, rimu and pukatea. Throughout its range, rimu is the most common podocarp. Native birds, especially kererū and tūī, are important for the pollination and seed dispersal of a wide range of canopy and sub-canopy species.

Threats: Occurring on the summits of steep and generally inaccessible ranges, this ecosystem type has had very little direct modification from humans, except for some localised selective logging of podocarps. Pest mammals have caused a decline in palatable canopy and sub-canopy species, such as northern rātā and raukawa, with a corresponding increase in non-palatable species such as hutu. Extensive dieback of northern rātā has been attributed to possum browsing (McKelvey & Nicholls 1959; Barton 1972). Goats are locally a threat, and in combination with possums and rats, have the potential to cause localised canopy collapse, regeneration failure and species loss (Payton 2000). Weeds are generally uncommon, however, and closed-canopy intact examples are relatively resistant to weed invasion, though shade-tolerant shrubs (e.g. privet) can invade (Wiser & Allen 2006).

Forest near the Kohukohunui summit of the Hunua Ranges. Possums and goats caused extensive dieback of northern rātā and other palatable forest species here in the past. **Jason Hosking.**

Forest understorey beside the Kohukohunui Track, Hunua Ranges. **Jason Hosking.**

MF25 Kauri, tōwai, rātā, montane podocarp forest

The forest-clad peaks of Hauturu (Little Barrier Island). **Alastair Jamieson.**

Regional IUCN threat status: Endangered

This higher-altitude forest ecosystem is very limited in extent. It is colloquially known as 'cloud forest' and includes the rare ecosystem 'Seabird burrowed soil' (Williams *et al.* 2007).

Distribution: Restricted to mild to cool and humid, predominantly rugged volcanic summits from the northern Kaimai and Coromandel Ranges (e.g. Mt Moehau) northwards, including Little Barrier Island (>600m) and Mt Hobson (Hirakimata) on Great Barrier Island. These summits experience high rainfall, long periods of cloud cover, infrequent snowfall and frequent high to gale-force winds, often from subtropical cyclones from the northeast (Ecroyd 1982). Owing to the age of landforms, high rainfall, and vegetation that forms acidic humus, the dense volcanic clays are strongly leached (Molloy 1998).

Characteristic native flora: Several variants occur, largely as a result of the presence or absence of conifer and broadleaved trees that reach their northern limits within the ecosystem. On the northern Kaimai and Coromandel Ranges and on Great Barrier Island, a low forest of kauri, podocarp and broadleaved trees occurs, with occasional kauri, yellow-silver pine, rimu, miro, monoao, toatoa and, locally, thin-barked tōtara, tāwari, tōwai, southern and Parkinson's rātā, and tāwheowheo.

Yellow-silver pine is locally more abundant where drainage is impeded. Characteristic sub-canopy and ground-cover species include three-finger, mountain five-finger, *Dracophyllum*, *Astelia* and *Gahnia* spp., kidney fern and abundant bryophytes (Nicholls 1976; Ecroyd 1982).

On Little Barrier Island, tāwari, tāwheowheo and southern rātā dominate, with occasional tōwai, thin-barked tōtara, toatoa, broadleaf, mountain five-finger, *Dracophyllum* spp. and *Archeria racemosa*. Dwarfed kauri and miro are found sparsely here (Hamilton 1961).

Characteristic native fauna:

Pre-human era: Kauri, tōwai, rātā, montane podocarp forest would have supported a range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Forest productivity would have been enhanced by the nutrients brought ashore by burrowing seabirds such as black and Cook's petrels (Atkinson & Millener 1991; Smith *et al.* 2011). Where kākāpō were present, summit ridges probably featured the track and bowl systems of this lek-breeding species (Merton *et al.* 1984), with the surrounding vegetation clipped back by the birds. Seasonal nectar sources from rātā spp. and tāwari would have been used by tūī, bellbird, hihi and geckos, while dracophyllum and *Archeria*, sedges, *Gahnia* spp. and flax would have been browsed by kākāpō. Insectivores could have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

Black petrel on Hirakimata (Mt. Hobson), Great Barrier Island. This ecosystem type occurs on the highest ridges of Great Barrier, which is now the most important breeding site for this threatened species. **Lyn Byrne, WMIL.**

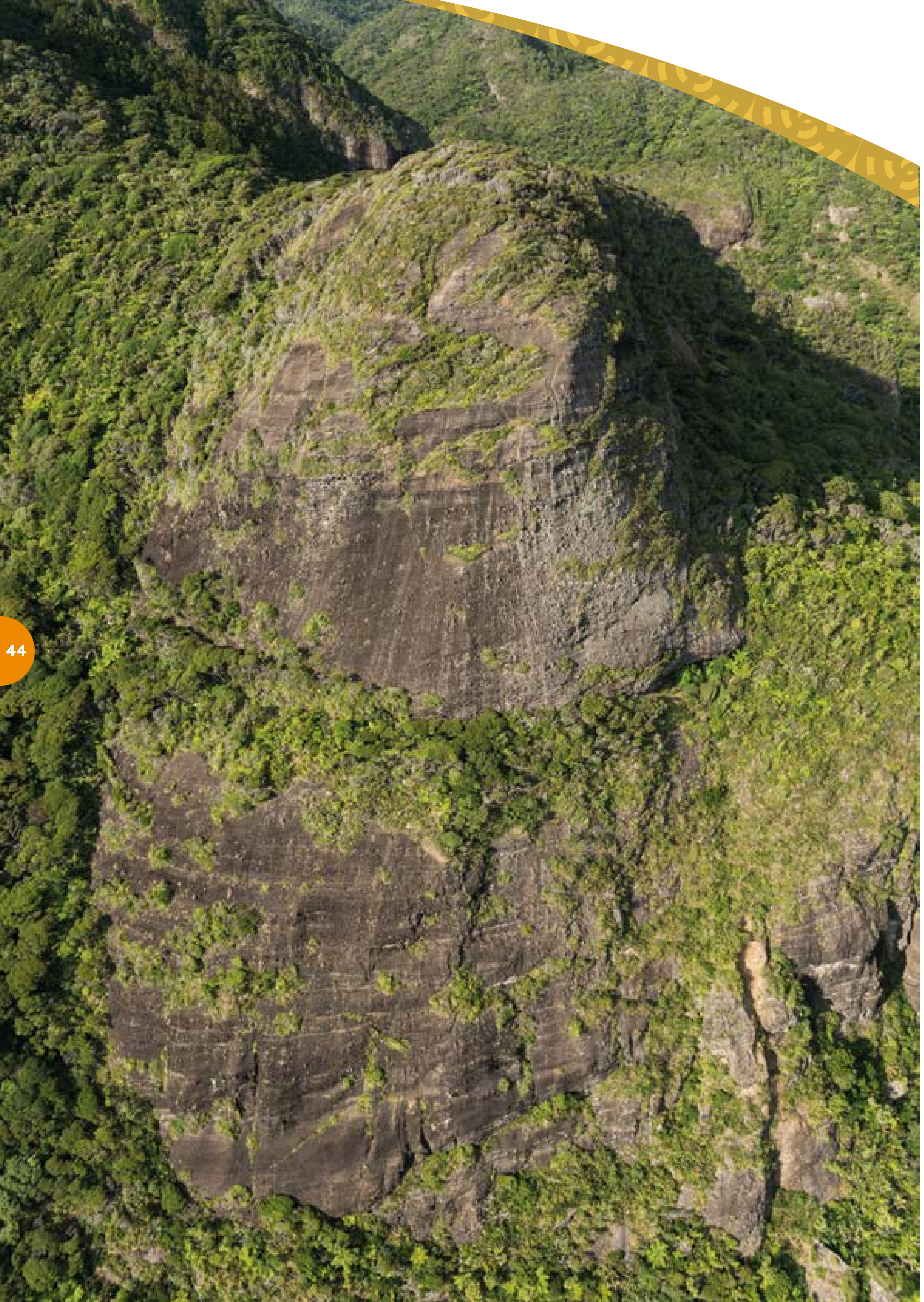
Forest understorey near the Mt. Hauturu summit. **Tim Lovegrove.**

Present: The most intact example of this ecosystem type exists on the summit ridges of Little Barrier Island, and a wide range of forest birds occurs there or visit seasonally, including kākāpō which have been introduced to the island. While this ecosystem is partly modified on Great Barrier Island by fire and the effects of introduced mammals, it still supports a colony of black petrels, and kākā, kākāriki, kererū, tomtit, fantail, grey warbler, silvereye, tūī and occasional bellbird. Introduced birds are sparse and include blackbird and chaffinch.

Key processes and interactions: Owing to exposed climatic conditions and infertile soils, species that normally occur at higher altitudes are found in this ecosystem type, with several species reaching their northern limits (e.g. toatoa and kaikawaka) (McEwen 1987). As a result, it is somewhat equivalent to the montane conifer–broadleaved forests of more southern mountains, although it is more species-diverse because of the inclusion of northern species (e.g. kauri and Kirk's pine).

Threats: This ecosystem type is geographically limited in extent and occurs almost entirely on public conservation land. Little and Great Barrier Islands have had no or few introduced predators and browsers, and where present most have been recently eradicated (e.g. cats and Pacific rats on Little Barrier and goats on Great Barrier Island), and their forest condition is improving. However, all have experienced some modification in the past or continue to do so. On the mainland, goats and possums have reduced the abundance of many palatable species (e.g. thin-barked tōtara and rātā species) (McCraith 2003). Pest mammals, especially rats, have reduced the number of common birds (Innes *et al.* 2010). Climate and inaccessibility means few weeds are present.

This ecosystem experiences few periods of soil moisture deficit. Perhaps the most significant potential threat is from drought due to climate change, which is predicted to occur more frequently from Waikato northwards (MAF 2009). Drought-induced forest mortality is becoming more frequent globally, and similar humid 'cloud' forests have been severely affected elsewhere (Allen *et al.* 2010).



Cliff ecosystems

Cliff ecosystems feature prominently throughout New Zealand and include cliffs, rocky outcrops, steep erosion-prone slopes and toe slopes. Abiotic factors strongly influence these ecosystems, with rock type, gradient, weathering and erodibility all factors in determining the suite of species that occupy them. Cliff ecosystems usually survive on minimal soils and are often subject to extreme environmental effects, such as high wind exposure, landslips and debris fall, and extremes of water saturation and drought. Plant communities may be highly fragmented and local endemism may occur as a result.

Of the 11 cliff ecosystem types recognised nationally, two occur in the Auckland region. Pōhutukawa treeland/flaxland/rockland (CL1) occurs on coastal rock faces and highly erodible hill-slopes around the coastline of the Auckland mainland and on offshore islands, including both Little and Great Barrier Islands. It comprises a mosaic of different plant communities, including trees, shrubs, flax and herbs. Many salt and drought-tolerant species occupy the microhabitats these cliffs provide. *Leptinella rotundata*, a coastal cliff species known only from the west coast of northern New Zealand, was presumed extinct in the Auckland region until a small population was discovered in 2010 in the Waitākere Ranges. Seabirds roost and breed on and near coastal cliffs, and contribute to nutrient cycling, particularly on offshore islands where predators have been eradicated and the birds are more abundant.

Hebe, wharariki flaxland/rockland (CL6) occurs on inland cliffs, rock outcrops and steep slopes, and along cliff seepages, streams and rivers. Cyclical disturbance creates the conditions for a mosaic of successional herbs, grasses, shrub and low forest species to regenerate. In Auckland a few species are associated mainly with cliffs. The Nationally Vulnerable Waitākere rock koromiko is known from only a small number of localities in the Waitākere Ranges, where it is found along stream edges, on rocky outcrops and near seepages along cliff faces.

The key threats to cliff ecosystems are environmental weeds, browsing mammals such as possums and habitat destruction. Some species, that are locally endemic and confined to small areas, are highly vulnerable to weed invasion. The loss of seabird colonies has reduced the natural fertility of some sites. Adaptive weed and pest management is critical to maintain cliff ecosystems, especially where vulnerable plant populations are limited in distribution and extent.

Image left: Bluffs below Baldy summit, Pararaha valley. **Alastair Jamieson.**

CL1 Pōhutukawa treeland/ flaxland/rockland

Regional IUCN threat status: Vulnerable

Pōhutukawa treeland on the steep cliffs of Hauturu/Little Barrier Island. **Tim Lovegrove.**

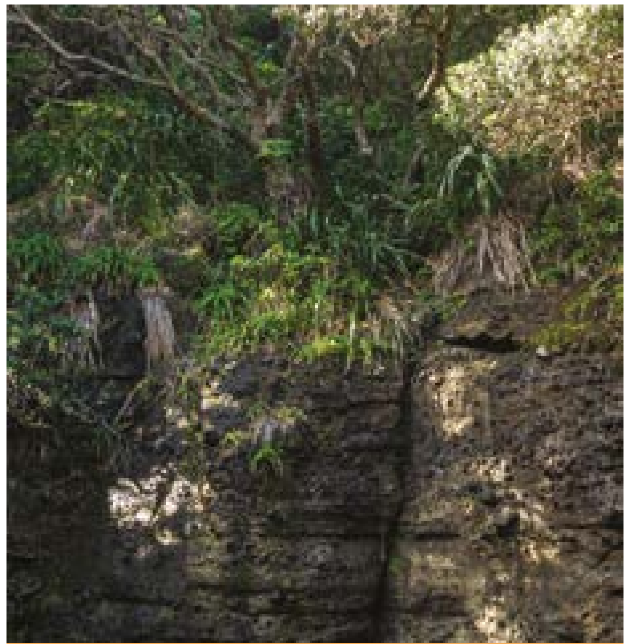
Steep, erosion and drought-prone slopes, salt spray and exposure to strong winds are the environmental factors which determine the composition and structure of this ecosystem. Plants found here are tolerant of high levels of salt on their leaves and in the soil.

Distribution: Coastal cliffs, highly erosion-prone hillslopes and colluvial slopes with pōhutukawa occur in frost-free mainland and island areas from the Three Kings Islands to northern Taranaki in the west and Poverty Bay in the east. This ecosystem is particularly abundant on many offshore islands, such as the Poor Knights, Little Barrier and Great Barrier Islands. It is common around Auckland's coastline with the best examples of this ecosystem type occurring on the south Muriwai to Waitākere coast and on the Hauraki Gulf Islands.

Characteristic native flora: A mosaic of treeland, shrubland, flaxland, herbfield and rock, with locally abundant pōhutukawa and occasional houpara, taupata, karo, kawakawa, New Zealand broom, hebe, harakeke, rengarenga lily, coastal astelia, knobby clubrush and, locally, coastal tussock. Halophytic herbs (e.g. New Zealand ice plant, pigweed, half star and shore celery) are often abundant on the rocky shore. Colluvial slopes and toe slopes at the base of cliffs and small gullies often include stunted coastal trees, such as karaka, kohekohe, tawāpou, wharangi and tūrepo. Flax and toetoe can be locally abundant in exposed and windswept locations. The ecosystem often includes small seeps with coastal wetland species such as slender clubrush. Northern offshore islands (e.g. the Three Kings, Poor Knights and Hen Islands) have additional endemic species, such as Poor Knights lily (Esler 1978a; Baylis 1986; Clarkson 1990; Wardle 1991; Lindsay *et al.* 2009). On the Waitākere coastline, *Leptinella rotundata*, a creeping perennial herb first described by Thomas Cheeseman over 100 years ago, was rediscovered in 2010, having been presumed to be locally extinct for some time.

Characteristic native fauna:

Pre-human era: This ecosystem would have supported a diverse range of invertebrates, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002). Ecosystem productivity would have been enhanced by the nutrients brought ashore by burrowing and surface-nesting seabirds (Atkinson & Millener 1991; Smith *et al.* 2011). On the mainland and Great Barrier Island, stout-legged moa could have browsed leaves and twigs and eaten fallen fruits, while nectivorous and frugivorous reptiles and birds would have benefited from an almost year-round food supply (Whitaker 1987; Clout & Hay 1989; Kelly *et al.* 2010). Little spotted kiwi were probably present, along with raptors, snipe and flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). Large-fruited trees, such as karaka, kohekohe, tawāpou and kohekohe, would have attracted frugivorous species, such as kākāpō, kākā, kererū, huia, saddleback, kōkako and piopio. Insectivores would have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).



Vegetation on the cliffs surrounding the blowhole at Piha. **Jason Hosking.**

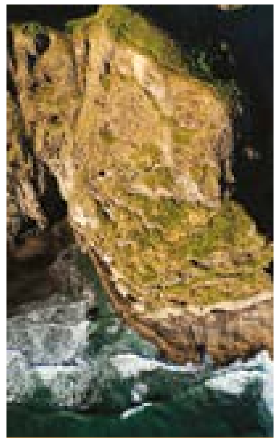
Little penguins or korora nest in burrows or natural cavities along the coastline. **Monique van Rensburg.**

Present: On pest-free offshore islands, this ecosystem may still have significant colonies of burrowing petrels and abundant skinks and geckos. Kākā, tūī, bellbird, saddleback, bats and geckos take abundant pōhutukawa nectar in season (Whitaker 1987; Clout & Hay 1989; Anderson 2003; Kelly *et al.* 2010). On the mainland, this ecosystem lacks petrel colonies but supports the more common native bush birds, such as morepork, kingfisher, shining cuckoo, fantail, grey warbler, tūī and silvereye, along with introduced blackbird, chaffinch, starling and myna.

Key processes and interactions: Unless buffered by frontal dunes or stony beaches, coastal cliffs are actively eroding (Kennedy & Dickson 2007). This greatly influences species composition which is a heterogeneous mix of plant forms that reflect micro-habitat, slope and aspect, and disturbance history. Being exposed, cliffs experience extreme weather from storms and the physical impacts of the sea, which erode soil, damage vegetation and cover plants in salt spray. In addition, cliffs experience significant periods of drought, especially if north-facing. Coastal cliffs host lichen, bryophyte, herb, grass, fern, shrub and small-tree species on the limited micro-habitats where soil forms or where their roots penetrate rock crevices.

Coastal cliffs are used by a wide range of seabirds (e.g. petrels, shags and gulls) as roosting and nesting sites, which add guano and increases nutrients. In pre-human times, seabirds would have been significantly more common.

Threats: Coastal cliffs are constantly suffering the impacts of the weather and the sea, causing vegetation disturbance and erosion. This allows a wide range of weeds to invade (Wiser & Allen 2006), including agapanthus, Mexican daisy, pampas, gorse, woolly nightshade, evergreen buckthorn, moth plant, boneseed and pines.



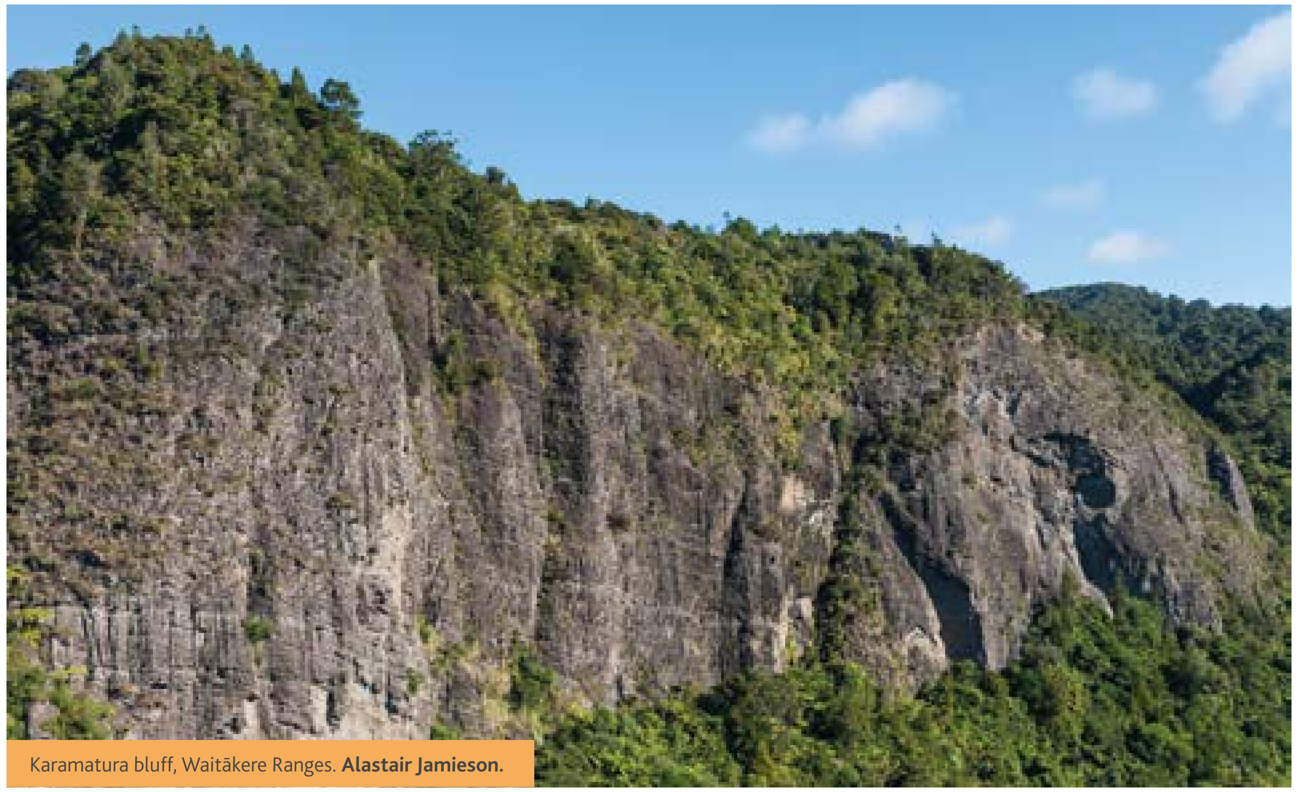
Te Ahua Point, Waitākere coastline. **Alastair Jamieson.**

On the mainland, possums are the most significant animal pest; they threaten the composition and structure, and have caused significant pōhutukawa dieback around the northern coastline (Payton 2000). Predatory mammals have also greatly reduced the numbers of seabirds, which in pre-human times would have been very abundant and would have brought nutrients ashore.

CL6

Hebe, wharariki flaxland/rockland

Regional IUCN threat status: Least Concern



Karamatura bluff, Waitākere Ranges. **Alastair Jamieson.**

This ecosystem occurs on cliffs, rock outcrops, and highly erodible steep slopes and colluvial deposits at the base of the slopes. The environmental factors that determine the composition and structure include slope steepness, rock type, its hardness, rate of weathering and erodibility, aspect, soil-moisture deficit and mass disturbance events. Periodic mass disturbance associated with high rainfall, soil saturation or earthquakes which cause mass slipping, results in cycles of primary succession. It occurs on a wide range of mainly siliceous acidic parent materials, such as mudstone, siltstone, sandstone, greywacke, ignimbrite and sandstones (e.g. Matemateāonga Ecological District), though locally it also occurs on limestone (e.g. Te Mata Peak) and basic volcanic rocks.

Distribution: Predominantly sub-humid and semi-arid zones of the North Island, from Northland to Auckland, East Cape to southern Wairarapa, and west into the Volcanic Plateau and Rangitikei district (Lake & Whaley 1995; Whaley *et al.* 2001; Beadle *et al.* 2004). It is rarer in humid areas where it generally occurs on north-facing and drought-prone slopes. This ecosystem type is most abundant along incised rivers in areas with highly erodible parent materials (such as mudstone/siltstone/sandstone) in the eastern North Island, and Rangitikei and Wanganui Districts. It is also associated with hard volcanic rocks throughout the central North Island and locally elsewhere. It also occurs on steep inland cliffs and bluffs in the Waitākere and Hunua Ranges (e.g. Pararaha) and on Little and Great Barrier Islands (e.g. Mt Hobson/Hirakimata).

Characteristic native flora: It occurs over a wide latitudinal and altitudinal range, with several regional variants, though regional compositional diversity is poorly understood because of a lack of ecological descriptions. Vegetation is successional, and composition and structure are strongly related

A range of low stature plants perched on ledges and in crevices within the splash zone of a waterfall, cascading down an inland cliff-face (Waitākere Ranges). **Jason Hosking.**

to slope steepness, rock hardness and time since mass disturbance, creating a mosaic of communities. Bare rock exposed from mass land movement is usually first colonised by a range of lichens and bryophytes, and on hard rock surfaces, lichens may be the dominant life-form, with few vascular plants. With weathering and soil accumulation, low herbs, grasses and wharariki colonise ledges and crevices.

Waitākere rock koromiko. **Peter de Lange.**

Later, shrubs, scrub and low forest species may enter. Many shrub and low-forest species present are generally representative of the surrounding forest and margins, though some specialists occur. Dominant species include wharariki, broadleaved poa, species of hebe, snowberry, New Zealand daphne, tree daisy, kōwhai and New Zealand broom, mingimingi, *Dracophyllum*, broadleaf, mānuka, tutu and locally, rātā lianes, ngaio, kānuka, perching lily, tūrutu and locally, tank lily and harakeke.

Wharariki. **John Sawyer.**

Waitākere rock koromiko is the only vascular plant endemic to the Waitākere Ranges, where it grows from the upper Anawhata and Waitākere Stream south to Destruction Gully (de Lange 2004).

Characteristic native fauna:
Pre-human era: Hebe, wharariki flaxland/rockland would have supported some invertebrates, reptiles and birds. On cliff ledges, where there was sufficient soil, a few burrowing petrels could have been present. Tūī, bellbird, saddleback, kōkako, bats and geckos would have taken flax nectar and small fruits in season (Whitaker 1987; Clout & Hay 1989; Anderson 2003; Kelly *et al.* 2010), while red-crowned kākāriki would have fed on the seeds of various shrubs, flax and grasses. Both kākāriki and saddlebacks would have roosted and nested in cliff cavities and under overhanging vegetation. Insectivores could have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

Present: On pest-free offshore islands, hebe, wharariki flaxland/rockland ecosystems may have some burrowing petrels, and skinks and geckos are common. Tūī, bellbird, kingfisher, saddleback and kākāriki are present, along with a few introduced species such as blackbird, starling and myna.

Key processes and interactions: This ecosystem includes many species that occur in a wide variety of other habitats, interspersed with specialists restricted to rocky habitats. Hard-rock cliffs have fewer vascular plants, because they are drought-prone and are more stable or slip infrequently. Softer rocks weather more quickly, forming pockets of raw soil that allow plants to establish more easily, although they slip more often. Over time, the vegetation succession can develop to scrub or a low forest and include species such as kōwhai, even on near-vertical faces.

Threats: Cliff habitats provide refugia from many threats, such as browsing mammals, fires and land development. Often in intensively developed agricultural areas, cliffs and steep slopes retain the last vestiges of indigenous vegetation. Despite this inaccessibility, the vegetation on these habitats has been reduced in extent and is often restricted to only the steepest areas, with the colluvial slopes being cleared of vegetation. Being high-light environments which are frequently disturbed, weeds readily invade (Wiser & Allen 2006), and numerous species of grass, shrub, liane and tree weeds (e.g. Mexican daisy, pampas, gorse, cotoneaster, and wilding pines) are significant threats.

Regenerating ecosystems

Regenerating ecosystems are those that occur following a natural disturbance (e.g. fire or volcanic activity), or revert following human disturbance, such as on abandoned farmland. They are an important stage of forest succession, providing valuable (often specialised) habitats for many native plants and animals (some of which are threatened), while allowing environmental conditions to develop for subsequent species colonisation.

In some situations, regenerating vegetation provides a physical buffer protecting more-mature ecosystem types from other land uses and edge effects. The vegetation of regenerating ecosystems may also reduce erosion, as it develops on bare ground.

In regenerating ecosystems, pioneering species typically arrive at a site, competing against other fast-growing species to establish themselves. In the Auckland region, mānuka and kānuka are common seral species (Kirk 1870; Esler 1991). They share two strategies: as either early successional, or permanently dominant species. Regenerating ecosystems are usually a temporary stage in the natural succession to more diverse and typically taller forest. In some circumstances, tall forest regeneration is stalled as a result of limited seed availability, or abiotic factors such as repeated disturbance, where soil erosion has exposed B and C soil horizons, or where soil moisture is limited.

In the Auckland region, regenerating ecosystems are a key part of the landscape and history. Four of the 14 regenerating ecosystems described nationally (Singers & Rogers, 2014) occur in the Auckland region.

These are pōhutukawa scrub/forest (VS1); kānuka scrub/forest (VS2); mānuka, kānuka scrub (VS3) and broadleaved scrub/forest (VS5). In addition, tōtara forest (AVS1) is regenerating, typically on unimproved pasture on hill country, which is grazed by cattle. These ecosystems are a familiar sight across the landscape. They occur in a diverse range of environmental contexts. Key threats to these ecosystem types include pest plants (especially fire-adapted species, those that can modify successional pathways or transform ecosystems); pest mammals (which browse palatable species and affect successional processes); physical isolation from other similar ecosystems; and clearance (for farming, urban development, and firewood). Regenerating ecosystems may be naturally short-lived, so the species adapted to them are vulnerable to environmental change caused by natural successional processes as the ecosystem develops into a mature forest. Active advocacy of the values of these often undervalued ecosystems is vital for their protection.

Image left: Scrub dominates the Kuataika area with Anawhata beach in the distance, Waitākere Ranges**. Alastair Jamieson.**

VS1 Pōhutukawa scrub/forest

Regional IUCN threat status: Endangered

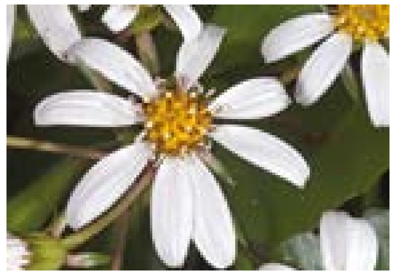
Forest colonising bare lava on Rangitoto Island. **Alastair Jamieson.**

Pōhutukawa is frost-sensitive and does not tolerate frosts below -3°C. It occurs naturally in northern New Zealand and in areas where frosts are mild, such as on the margins of lakes. It tolerates a wide range of soil conditions varying in fertility and acidity.

Distribution: Primarily coastal northern North Island and localised places in the Rotorua Lakes Ecological District, e.g. lower slopes of Mt Tarawera. The best example of this ecosystem type in the Auckland region is on Rangitoto Island.

Characteristic native flora: Pōhutukawa and pōhutukawa-northern rātā scrub/forest of a range of variants, often in association with kānuka. Common associates on lava on Rangitoto Island include peperomia, puka, karamū, akepiro, hebe, Kirk's daisy, māpou and coastal astelia. Associates on scoria include mānuka, rewarewa, māhoe, akeake, tutu and māpou.

Characteristic native fauna:
Pre-human era: On Rangitoto, the pre-human fauna was probably quite depauperate, especially during the early stages of forest succession, and it would have mainly comprised those species able to cross from nearby Motutapu Island and colonise young forest patches on otherwise inhospitable bare lava. Invertebrates would have included species able to survive in moist crevices in the lava, or in small patches of young pōhutukawa scrubland. Reptiles could have included tuatara and a few skink and gecko species (Atkinson & Millener 1991, Miller *et al.* 1994). Tuatara would have taken large invertebrates such as wētā, while in addition to invertebrate foods, geckos would have foraged on pōhutukawa and rātā nectar and small fruits such as māpou in season (Whitaker 1987). Amphibians were possibly absent. The young forest could have supported a range of terrestrial birds and among these, raptors and insectivorous species would probably have predominated (Miller *et al.* 1994).



Birds could have included harrier, falcon, New Zealand quail, banded rail, spotless crake, red-crowned kākāriki, shining cuckoo, morepork, kingfisher, pipit, grey warbler, fantail, tomtit, bellbird, tūī and perhaps saddleback. Long-tailed bats could have inhabited some of the lava caves. During later stages of forest succession, especially around the base of the cone, where the pōhutukawa forest merges with the more diverse forest growing on ash, additional bird species such as kereru and kākā were probably present (Miller *et al.* 1994). Other birds such as yellow-crowned kākāriki, rifleman, whitehead and robin could also have been present. Some of these birds would have also foraged in the nearby pōhutukawa forest.

Present: During the period when mammalian pests were present, Rangitoto's pōhutukawa forests supported few reptiles and birds. Along the coast, Suter's skinks were common and found refuge under seaweed along the tide wrack and amongst the lava cobbles and crevices, while the pōhutukawa forest supported a similar range of native bush birds to the nearby mainland including morepork, kingfisher, shining cuckoo, grey warbler, fantail, silvereye and tūī. Tomtits recolonised naturally during the 1990s before all of the pests were removed. Following the eradication of all mammalian pests (Griffiths 2011), whitehead and saddleback have been reintroduced, while kākā, red-crowned kākāriki and bellbirds have begun to recolonise naturally. Common introduced birds include rosella, blackbird, song thrush, chaffinch, greenfinch, goldfinch, house sparrow, starling and myna.

Key processes and interactions: Pōhutukawa is extremely well adapted to colonising bare ground and is often abundant on exposed shoreline margins, where it is able to tolerate salt-laden winds (Bergin & Hosking 2006). Having wind dispersed seeds, it readily establishes over long distances as a primary coloniser of vegetation successions following fire or volcanic activity. On Rangitoto Island it has colonised aa and pahoehoe lava, while on White Island it occurs on andesitic lava and tephra and is regularly damaged by eruptions (Clarkson 1990). On northern offshore islands, such as the Poor Knights and Mayor Islands, pōhutukawa dominates vegetation succession following anthropogenic fires and human decolonisation (Atkinson 2004; Wilmshurst *et al.* 2014).

Pōhutukawa can develop into near monocultures of tall forest, capable of dominating for several centuries (Atkinson 2004), though generally succeeds to pōhutukawa, pūriri, broadleaved forest (WF4).

Threats: Pōhutukawa is palatable to a wide range of introduced pest mammals, including possums, wallabies, rabbits and ungulates, though many of these pests have now been eradicated from significant areas, e.g. Rangitoto and Mayor Islands. Possums have caused significant dieback of pōhutukawa locally throughout northern New Zealand, and effective possum control is essential if we are to maintain this ecosystem on the mainland. This ecosystem type is invaded by a wide range of shrub, tree and climbing weeds, including evergreen buckthorn, tree privet, wilding pines and moth plant. These weeds threaten this ecosystem by altering successional pathways.

Images:
Top: Pōhutukawa or pōhutukawa x northern rātā hybrid. **Alastair Jamieson.**
Bottom left: Kirk's daisy. **Jeremy Rolfe.**
Bottom right: *Peperomia urvilleana.* **John Sawyer.**

VS2 Kānuka scrub/forest

Regional IUCN threat status: Least Concern

Kānuka scrub/forest at Karekare. **Jason Hosking.**

Kānuka (*Kunzea* spp.) includes 10 closely related species of which most occur in early vegetation successions (de Lange 2014). As a result of frequent fires, kānuka scrub occupies many sites that were formerly tall forest (Wardle 1991). Kānuka scrub is promoted by fire over many decades, or even centuries, which prevents its replacement by tall forest species, such as beech and podocarps. However, fires that occur too frequently remove kānuka seed sources and may promote fast-growing, non-woody and fire-resistant species, such as grasses and bracken (Burrell 1965).

Distribution: Occurs throughout New Zealand from North Cape to Otago. As a dominant kānuka scrub community, it is prevalent in warm to cool, semi-arid climates throughout the eastern North and South Islands. It also occurs locally in sub-humid climates, such as Northland to the Waikato, Bay of Plenty, central North Island, Manawatu–Wanganui and Nelson. In these regions it is generally restricted to well-drained soils and other sites which experience summer droughts, such as north-facing hill-slopes and recent alluvial or sandy raw soils. Kānuka is highly competitive in semi-arid climates and sites that are too dry for mānuka, predominating vegetation successions for example in Otago, where rainfall is less than 650mm (Burrows 1973), and similar sites in Canterbury, such as Rakaia Island (Meurk 2008). Kānuka is frost-tolerant and its upper altitudinal limit is approximately 1000m on the Volcanic Plateau (Rogers & Leathwick 1994). Kānuka scrub/forest is widespread throughout the Auckland region.

Coprosma rhamnoides. **Jeremy Rolfe.**

Characteristic native flora: Kānuka scrub occurs over a wide latitudinal and altitudinal range, and variable regional vegetation successions exist that are representative of local conditions and available seed sources. Kānuka may establish on bare ground following fire and also locally colonise gaps in sparse grasslands. Transitional communities often contain a wide variety of grassland and scrub species such as *Schoenus tendo*. Some associate species are almost ubiquitous throughout its range such as tall mingimingi, prickly mingimingi, *Coprosma rhamnoides* and tauhinu (Wardle 1991; Allen *et al.* 1992; Ecroyd & Brockerhoff 2005; Sullivan *et al.* 2007). Māhoe, five-finger, hangehange, lancewood, kōwhai, karamū and putaputawētā are also common associates in most regions as stands mature, except in the driest sites. Kānuka scrub also provides ideal conditions for the regeneration of many tall forest trees including podocarps such as tōtara, mataī and tānekaha (Wilson 1994; Sullivan *et al.* 2007; Esler & Astridge 1974; Rogers & Leathwick 1994). Tōtara often replaces kānuka scrub/forest, especially in association with grazing in northern New Zealand.

Characteristic native fauna:
Pre-human era: As with other forest ecosystems, kānuka scrub/forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002), especially in those places where forest succession was well advanced. At some sites, forest productivity would have been enhanced by the nutrients brought ashore by burrowing and surface-nesting seabirds (Atkinson & Millener 1991; Smith *et al.* 2011). Several species of moa, adzebill, brown and little spotted kiwi and weka were probably present, along with forest-inhabiting ducks, raptors, snipe and smaller flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). The drier, younger forest stages might have had fewer large frugivores, such as kererū and kōkako, but a higher proportion of insectivorous species, such as tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, whitehead, tomtit, robin, huia, saddleback and piopio, while kānuka honeydew would have attracted hihi, bellbirds and tūī. Geckos would have been abundant in kānuka forest, and they would have fed on honeydew along with the fruits of various small-fruited shrubs and trees (Whitaker 1987).

Present: Kānuka forests in places with few or no pest mammals can support very high reptile and bird densities of a wide range of species. There is often a high turnover of dead wood, so invertebrates are abundant. The understorey may have a diverse range of flowering and fruiting shrubs. Kānuka forests have some geckos and all of the more common native bush birds, such as kererū, morepork, kingfisher, shining cuckoo, fantail, grey warbler, tūī and silvereye, with additional species such as kākā, kākāriki, long-tailed cuckoo, rifleman, whitehead, robin, tomtit, hihi, bellbird, saddleback and kōkako on islands lacking predatory mammals. Introduced birds include brown quail, rosella, dunnock, blackbird and chaffinch.

Key processes and interactions: Kānuka has highly mobile, wind-dispersed seed that germinates in high-light conditions (Burrows 1973). It quickly invades disturbed sites following fire, flooding and other forms of land erosion, and readily regenerates into spaces in short-tussock grassland and herbfield (Allen *et al.* 1992), forming a dominant successional community. Kānuka locally replaces mānuka, kānuka scrub (VS3) in sub-humid zones (Stephens *et al.* 2005). In pre-human times, kānuka scrub would have been most abundant on sites too dry or too frequently disturbed to support tall forest (Smale 1994), such as adjacent to braided rivers and stable dunes. Without a major disturbance, kānuka scrub throughout most of its range is invaded by a wide range of shrubs and trees, both broadleaved and podocarp. With sufficient time, it develops into a forest that becomes increasingly diverse with age. Kānuka communities can be long-lived, remaining for 80–150 years, though some trees can survive up to 250 years, reaching 30m in optimal sites (Burrows 1973; Dawson & Lucas 2011). On extreme edaphically dry sites (Burrell 1965), or places where browsing mammals are common (Payton *et al.* 1984; Smale *et al.* 1996), kānuka may regenerate beneath itself.

Tomtit. **Tim Lovegrove.**

Threats: Kānuka scrub has probably increased in abundance since pre-human times through being highly competitive in vegetation successions following fire, especially in semi-arid regions (Wardle 1991). Kānuka is unpalatable to stock and ungulates, and readily invades erosion-prone hill-slopes and low-producing pasture (Payton *et al.* 1984; Smale *et al.* 1996, 1997). Burning and land development for forestry and agriculture mean that kānuka scrub is locally rare and threatened, including some regions or habitats where it was once common, such as adjacent to braided rivers on the Canterbury Plains and on stable dunes throughout New Zealand. Leguminous weeds, such as gorse, broom and tree lupin, have largely displaced it as the primary coloniser in much of its former riparian habitat, and also in areas suitable for tall forest (Sullivan *et al.* 2007; Williams & Wiser 2004). Kānuka scrub is also invaded by a very wide range of weeds, though shrub and tree weeds (e.g. gorse, broom, wilding pines, wattles and privet) are arguably of greatest threat, because they potentially displace and modify successional pathways.

VS3 Mānuka, kānuka scrub

Regional IUCN threat status: Least Concern

Mānuka, kānuka scrub. **Jason Hosking.**

Mānuka and kānuka have two similar ecological roles and regeneration strategies (Burrows 1973): permanent dominance on extreme sites, and/or as early successional species (Wardle 1991). In extreme environments, mānuka occupies areas that are wet, cold, exposed, infertile or unstable for tall forest (Burrows 1973), while kānuka occupies sites that are dry (Burrell 1965). Where niches overlap for both species, they form the dominant early-successional woody community. This is most prevalent on free-draining soils suitable for indigenous forest throughout sub-humid and humid zones from coastal to montane regions. Mānuka and kānuka have similar tolerance of frost (from -9°C to +/- 1°C) (Bannister 2007), although the upper altitudinal limit of kānuka is lower (at approximately 1000m) on the North Island Volcanic Plateau (Rogers & Leathwick 1994).

There are two regional variants:

- VS3.1: A mosaic of kānuka and mānuka dominated scrub.
- VS3.2: Mānuka dominated scrub.

Distribution: Occurs throughout most of New Zealand's sub-humid climatic zones, on a wide range of generally free-draining soil and landform types, from warm Northland to cool coastal Otago.

Mānuka, kānuka scrub is abundant in the Waitākere Ranges and on Great Barrier Island.

Characteristic native flora: Having a wide latitudinal and altitudinal range, this ecosystem has many local compositional variants. In warm to mild sub-humid regions, colonising broadleaved shrub and tree species include hangehange and māhoe, species of *Coprosma*, *Pittosporum* and *Pseudopanax*, locally kawakawa, māpou and rewarewa. Tree ferns (e.g. mamaku and ponga) also establish in humid micro-sites, such as in gullies. Where seed sources are present, kauri, podocarp, and broadleaved canopy trees establish early in the succession and ultimately replace kānuka in the canopy (Esler & Astridge 1974; Smale 1993a, 1993b).
This pattern is mirrored in other regions, though species differ from region to region.

Mānuka. **John Sawyer.**

Characteristic native fauna:
Pre-human era: As with other forest ecosystems, mānuka, kānuka scrub would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002), especially in those places where succession was well advanced. Two or three species of moa, adzebill, brown and little spotted kiwi and weka were probably present, along with forest-inhabiting ducks, raptors, snipe and smaller flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). As with kānuka forest, the younger kānuka, mānuka scrub might have had fewer large frugivores, such as kererū and kōkako, but a higher proportion of insectivorous birds, such as wrens, fernbird, whitehead, tomtit, robin, saddleback and piopio, while kānuka honeydew, where present, would have attracted hihi, bellbird and tūī. Geckos would have been abundant in mānuka, kānuka scrub, and they would have fed on kānuka honeydew along with the fruits of various small-fruited shrubs and trees (Whitaker 1987).

Present: Mānuka–kānuka scrub in places with few or no pest mammals can support a wide range of reptiles and birds. There is a high turnover of dead wood, so

Forest gecko. **Dylan van Winkel.**

invertebrates are abundant. The understorey may have a range of flowering and fruiting shrubs. This ecosystem type has some geckos and all the more-common native bush birds, e.g. kererū, morepork, kingfisher, shining cuckoo, fantail, grey warbler, tūī and silvereye, with additional species such as yellow-crowned kākāriki, long-tailed cuckoo, rifleman, whitehead, robin, tomtit, hihi, bellbird and saddleback on islands lacking predatory mammals. Fernbirds may be present in young mānuka–kānuka scrub. Introduced birds include brown quail, dunnock, blackbird and chaffinch.

Key processes and interactions: As a successional community, this ecosystem occurs where forest establishment is prevented or stalled by site conditions (Esler & Astridge 1974; Rogers & Leathwick 1994; Wardle 2001). Mānuka and kānuka establish concurrently following a disturbance event such as fire. Either species may dominate or be co-dominant in the initial primary succession phase, depending on the local micro-site circumstances, producing a tightly stocked stand of up to 80,000 trees per hectare, with few other species. This progressively thins over time, producing a dense leaf-litter layer (Smale 1993b). Growing taller, kānuka replaces mānuka and overtops its competitor (Stephens *et al.* 2005). In lowland coastal sites, this can take as little as 20–30 years (Esler & Astridge 1974; Allen *et al.* 1992), while in montane sites, it can be as long as 70 years (Rogers & Leathwick 1994).

Thinning of kānuka occurs progressively, which allows more light to penetrate to the forest floor, producing near-ideal semi-shade conditions for seedling establishment of a wide range of sub-canopy and canopy trees and shrubs. On Little Barrier Island, stand density reduced to 600 trees per hectare at 60–70 years (Smale 1993b), and it has been predicted that most trees would be replaced within 150 years from germination. Similarly, a study in the Golden Bay region, found that kānuka stands 100 years old were overtopped at around 40 years by taller-growing species. By 100 years, the kānuka canopy was expected to be shared by an equal abundance of kānuka and pole-sized canopy trees, such as various podocarps, silver beech, kāmahi and northern rātā (Bray *et al.* 1999).

Depending on available seed sources and local conditions, a wide variety of other species establish, eventually developing into tall forest where conditions allow. With increasing time, there is a general trend of species colonisation, with initially only wind-dispersed species, then species with small fleshy fruits followed by those with large fleshy fruits (Bray *et al.* 1999). This is a pattern that represents use of the stands with time by small birds (e.g. silvereye and bellbird) and then larger birds (e.g. kererū and tūī) (Williams & Karl 2002).

Self-perpetuation of this ecosystem requires frequent disturbance, usually by fire, on a multi-decade time scale (Wardle 1991).

Threats: This ecosystem has increased greatly since pre-human times as a result of widespread Māori and European deforestation (Wardle 1991). The greatest long-term threat is now posed by competition from a wide range of weeds, especially species that are fire-adapted, such as gorse, broom, species of hakea, wattle and wilding pines. These produce large, long-lived seedbanks that readily germinate after fire and can out-compete mānuka and kānuka during the initial colonisation phase. Older mānuka, kānuka scrub (VS3) is also invaded by a wide range of weeds, especially bird-dispersed trees, shrubs and lianes, such as tree privet, cotoneaster, blackberry and Japanese honeysuckle.

Mānuka and kānuka are both unpalatable to stock, ungulates and possums, and readily invade erosion-prone hillslopes and low-producing pasture (Smale *et al.* 1997). While neither is directly affected by grazing or pest animals, they alter successional processes and prevent canopy species establishing. This leads to vegetation succession being dominated by unpalatable species, such as various podocarps, with fewer palatable broadleaved species (Bray *et al.* 1999) and, locally, multiple cohorts of kānuka (Payton *et al.* 1984).

VS5 Broadleaved species scrub/forest

Regional IUCN threat status: Least Concern

Broadleaved species scrub/forest is most abundant on low-fertility hill-slopes that were formerly forested, particularly in sub-humid, humid and higher rainfall regions.

Distribution: From Northland to Stewart Island, although it is also locally present in semi-arid regions. Found throughout the Auckland region, but particularly common on south-facing slopes in southern parts of the region.

Characteristic native flora: This ecosystem type has a wide latitudinal and altitudinal range, with many local compositional variants, often growing within a mosaic with other advanced successional communities, such as mānuka–kānuka scrub (VS3) or tree ferns. It is dominated by short-lived species commonly found in the sub-canopy or on the margins of mature forest. Throughout its range it may include species of *Coprosma* (especially karamū, shining karamū and kanono), *Pseudopanax*, *Pittosporum*, tree daisy, hebe, lacebark, rangiora, tutu, putaputawētā, māhoe, māpou and wineberry. Locally in gullies and in humid climates, kōtukutuku, patē, kāmahi and tree ferns (including mamaku, ponga and whekī-ponga) may be abundant. In sub-humid and semi-arid regions in eastern New Zealand, species of kōwhai, ribbonwood, kaikōmako and locally, cabbage trees and ngaio occur, and in cool climates, broadleaf (Wardle 1991).


Putaputawētā. **John Sawyer.**

Broadleaved species scrub/forest of northern New Zealand is often dominated by māmāngi and māpou (Burns & Leathwick 1996), e.g. in localised areas within the Waitākere Ranges.


Regenerating forest. **Jason Hosking.**

Characteristic native fauna:
Pre-human era: As with other forest ecosystems, broadleaved species scrub/forest would have supported a diverse range of invertebrates, amphibians, reptiles, birds and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002), especially in those places where forest succession was well advanced. Two or three species of moa, adzebill, brown and little spotted kiwi and weka were probably present, along with forest-inhabiting ducks, raptors, snipe and smaller flightless rails (Atkinson & Millener 1991; Worthy & Holdaway 2002; Holdaway *et al.* 2013). Broadleaved scrub/forest would have supported frugivores, such as kererū and kōkako, along with insectivorous and frugivorous birds, such as whitehead, tomtit, robin, hihi, bellbird, tūī, saddleback and piopio. Geckos would have been abundant, and they would have fed on invertebrates and the fruits of various small-fruited shrubs and trees (Whitaker 1987).


Tree ferns are abundant in this forest type. **Jason Hosking.**

Present: Broadleaved species scrub/forest in places with few or no pest mammals can support a wide range of reptiles and birds. There is a high turnover of dead wood, so invertebrates are abundant and there are many flowering and fruiting shrubs. This ecosystem type has some geckos and all the more common native bush birds, e.g. kererū, morepork, kingfisher, shining cuckoo, fantail, grey warbler, tūī and silvereye, with additional species such as kākāriki, long-tailed cuckoo, rifleman, whitehead, robin, tomtit, hihi, bellbird, saddleback and kōkako on islands lacking predatory mammals. Introduced birds include rosella, dunnock, blackbird and chaffinch.

Key processes and interactions: Broadleaved species scrub/forest is an advanced stage of forest succession, often replacing bracken (Wardle 1991; McGlone *et al.* 2005) or mānuka (Stephens *et al.* 2005), both pioneer colonisers after major disturbance events, such as volcanic eruptions (Wilmshurst & McGlone 1996). Since European colonisation, it more commonly occurs in areas of abandoned hill-country pasture of low productive value that were formerly forest (Newsome 1987). It also replaces a pioneer succession of gorse (Wilson 1994; Sullivan *et.al* 2007) or broom (Williams 1983). Many broadleaved scrub species have small, bird-dispersed fruits that are eaten by a wide range of native and introduced birds. Successional pathways and forest composition are greatly influenced by the variety and abundance of neighbouring seed sources rather than seed dispersers (Williams & Karl 2002).

Threats: As this ecosystem type is often dominated by palatable species, such as five-finger and māhoe, it can support high populations of browsing mammals. Prolonged pressure by browsers eventually depletes palatable species (Payton 2000), favouring succession towards non-palatable species, such as ponga and podocarps (Wardle 1991).

Weeds are also locally significant threats, especially close to residential areas. Many weed species, such as gorse, Himalayan honeysuckle and broom, will generally be suppressed and become increasingly uncommon with succession (Williams 2011). The greatest threat is posed by species capable of causing ecosystem transformation, including climbing vines, such as Japanese honeysuckle and banana passionfruit, or trees such as privet (Wilson 1994, 2003; Williams 2011).


Image right: Silvereyes are very common in scrub forests and disperse the seeds of many small-fruited species. **Geoff Moon.**

Wetland ecosystems

Wetland ecosystems are ecologically sensitive, diverse places where water is a dominant environmental factor, and the plants and animals living there have adapted to living in the wet and often changeable conditions.

Wetlands form a vital link between land and water, and are uniquely shaped by a number of interconnected factors, especially the volume, velocity, salinity and permanence or transience of water.

Underlying geology, the soil, climate, ground-water levels, water fertility and chemistry, and the plants and animals living in them also strongly influence the characteristics of wetlands.

Wetlands are among the world's most productive environments and provide a range of 'ecosystem services'. These include storing and purifying water, providing flood and erosion amelioration, ground-water replenishment, providing nurseries and habitats for native fish and eels, supporting a wide range of threatened plant and animal species, retaining nutrients and sediments, providing carbon storage, and delivering recreational opportunities.

Wetlands support a greater diversity of native birds, fish, invertebrates and plants than many other habitat types. They may also have cultural and spiritual significance to iwi.

Lowland wetlands are amongst the most threatened ecosystems in New Zealand, having suffered extensive loss as a result of drainage and land clearance. As a consequence, protecting remaining wetlands is considered to be a priority both in an Auckland regional and national context.

Cabbage tree and flax swamps inhabited by weka, banded rail, crakes, bittern, waterfowl and pūkeko were once common in the low-lying suburbs of the Auckland isthmus. Wetlands occurred where lava flows had impounded streams, or in volcanic craters and lava-flow depressions (Hochstetter & Peterman 1864). Swamp forests with kahikatea, pukatea, swamp maire, raupō, cabbage trees and harakeke covered large expanses of river flats and other poorly-drained land on the Kaipara, Franklin and Rodney lowlands. At the coast, freshwater wetlands graded into salt marshes vegetated with oioi and sea rush. Numerous dune lakes and associated wetlands occurred in depressions in the sand-dune country on the Āwhitu and Kaipara South Head peninsulas, and along the Pakiri to Mangawhai dune lands.

Eight of the 21 national wetland ecosystem types occur in the Auckland region (Singers & Rogers, 2014). Drainage and fertility are key controlling factors for the vegetation communities in wetland ecosystems. The Auckland wetland ecosystem types (described in detail below) range from the relatively uncommon mānuka, gumland grass tree, *Machaerina* scrub/sedgeland [gumland] (WL1), through to the more-common (but still Endangered) scattered raupō reedland in rural parts of the region (WL19).

Wetlands are highly sensitive, and in the Auckland region they continue to be threatened by ongoing drainage, invasive pest animals and weeds, pollution and damage from livestock. Well-informed management and appropriate restoration can help to protect and enhance our remaining wetlands, and prevent further losses.

Image opposite:
Te Henga/Bethells wetland is one of Auckland's largest wetlands.
Alastair Jamieson.

WL1

Mānuka, gumland grass tree–*Machaerina* scrub/sedgeland [Gumland]

Regional IUCN threat status: Critically Endangered


Gumland. **Jason Hosking.**

Gumlands occupy some of the lowest-fertility soils in New Zealand and occur on landforms of low relief (<5°) (Clarkson *et al.* 2011). The soils, known as kauri podzols or Wharekohe and Te Kopuru soils (Molloy 1988), have formed over thousands of years in humid areas, often with low-nutrient parent material and acid kauri leaf litter, which has leached base elements below the root zone, creating a podzol. As a result, drainage is strongly impeded and these soils are saturated for months, although some gumland soils can be seasonally dry (e.g. Waikumete and Te Kopuru).

Gumland vegetation probably expanded as a result of pre-European fires (Esler & Rumball 1975; Clarkson *et al.* 2011). Periodic natural fires may have also halted succession to taller scrub and maintained the characteristic low-stature vegetation. This ecosystem includes the nationally rare ecosystem 'gumlands' (Williams *et al.* 2007).

There are two variants:

- WL1.1: True gumland heath (per Clarkson *et al.*, 2011), e.g. Waikumete Cemetery.
- WL1.2: Mānuka on poorly drained substrates but without all the key characteristics of true gumland heath, which include podzol and ultic soils (strongly leached and acidic), seasonal waterlogging, low nutrients and occasional fires.

Distribution: Occurs in Northland, Auckland and Coromandel regions north of 37°S, congruent with the distribution of kauri. The only example of true gumland in the Auckland region (according to the Clarkson *et al.* 2011 definition) is found at Waikumete Cemetery. Other areas colloquially known as gumland (WL1.2), but not fully meeting the above definition, include sites in Albany, Ōrewa and on the Whangaparāoa Peninsula.

Characteristic native flora: Gumland vegetation is characterised by low scrub, sedgeland and fernland. Six gumland communities have been identified, reflecting differences in drainage, rainfall, altitude, nutrients and time since fire (Clarkson *et al.* 2011). Broadly speaking, there are two vegetation patterns, with mānuka and gumland grass tree on better-drained sites, and tangle fern in the poorly-drained, higher-nutrient sites. Other co-occurring plants in these communities include species of *Machaerina*, *Schoenus*, *Gahnia*, *Tetraria* and *Lepidosperma* sedges, and locally, tamingi. Gumlands support a wide range of threatened plants, including many ground orchids (de Lange *et al.* 2009).

The composition of pre-Māori gumlands is poorly known, however they probably contained a greater diversity and abundance than today of woody species tolerant of low fertility and seasonally wet conditions, such as yellow-silver pine, monoao, rimu and locally, kauri. These species would have been stunted shrubs to small trees, interspersed with other species such as tōwai, forming a taller-statured ecotone, where gumlands merged into taller forest.

Characteristic native fauna:
Pre-human era: There is little information on the pre-human fauna of these wetland ecosystems, but some of them were possibly used by Mantell's moa, which favoured wetlands and wetland margins (Tennyson & Martinson 2006). Birds that fed, nested or sheltered in these ecosystems could have included adzebill, flightless goose, swan, Australasian and little bitterns, various ducks, rails, snipe and passerines, especially fernbird (Atkinson & Millener 1991; Worthy & Holdaway 2002). Bird numbers and species composition would have fluctuated in some of these ecosystems in response to prehistoric fires, which would have opened up the habitat from time to time. Several gecko species, including green and forest geckos, were probably also present.

Present: Fernbird commonly occur in these ecosystems, and green and forest geckos occur where mānuka and tangle fern are present.

Key processes and interactions: The key processes that determine vegetation communities in this ecosystem are drainage and fertility. Most species that occur are either fire-resistant (e.g. sedges and ferns that re-sprout from rhizomes), or fire-promoted (e.g. mānuka that regenerates on bare surfaces) (Clarkson 1997). Gumland vegetation has fewer endemic species (47 per cent) than the New Zealand average (82 per cent), and many of the species (44 per cent) are shared with Australia (Clarkson *et al.* 2011).

Threats: Gumlands have been greatly reduced in extent since the 1840s, when they occupied approximately 300,000ha, although this figure included areas that were likely induced by pre-European fires (Clarkson *et al.* 2011). Many gumlands were mined for kauri gum which involved burning, substrate excavation and scouring, further reducing fertility and often leaving areas with exposed soil pans (Clarkson *et al.* 2011). Gumlands have also been developed into pasture with the addition of fertiliser (Molloy 1998). They are invaded by weeds, especially species that are adapted to nutrient-poor, water-logged conditions (e.g. Spanish heath, gorse, pines and hakea). The dominant hard-leaved, nutrient-poor vegetation means that animal pests are a relatively minor threat. Fire has both positive and negative effects: it maintains low-stature communities, and facilitates natural succession and habitat for early successional species, while also promoting the spread of fire-adapted weeds (e.g. gorse and hakea). Frequent Māori and early European fires probably exterminated slow growing, long-lived woody species such as silver pine, yellow-silver pine, Kirk's pine, rimu and kauri.


Image above: Auckland green gecko. **Dylan van Winkel.**

WL2 Mānuka, greater wire rush, restiad rushland

Regional IUCN threat status: Critically Endangered

This ecosystem occurs in inland wetlands in northern, warm and sub-humid areas that range in age from 1500–7000 years old (Clarkson *et al.* 2004). The soils are organic and the fertility is mesotrophic (fen). The water table fluctuates, being saturated for most of the year, but possibly dry during extended periods without rainfall (generally in late summer).

Distribution: Palustrine wetlands from Northland to Waikato lowland plains (e.g. Motutangi Swamp, Northland, and Whangamarino, Waikato). Found on the margins of some dune lakes in the Auckland region.

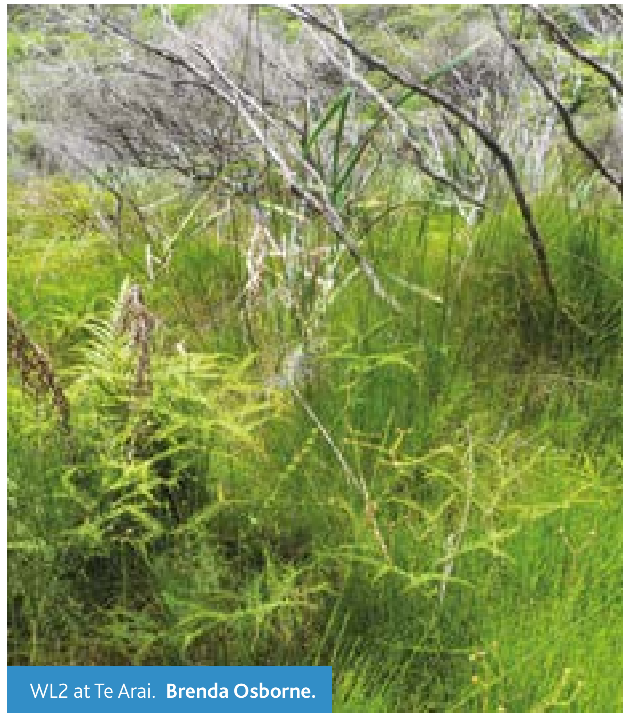
Characteristic native flora: This wetland ecosystem type is a species-poor (Clarkson *et al.* 2004) scrub/restiad rushland. It typically has a canopy of mānuka, occasional tamingi, with a sub-canopy of dense greater wire rush, scattered tangle fern and locally, *Schoenus brevifolius*. Other co-occurring species include *Machaerina tenax* and *Tetraria capillaris* (Ogle & Bartlett 1981; Clarkson 1997).

Pre-Māori, this ecosystem likely had a greater diversity and abundance of woody species tolerant of seasonally wet conditions, such as silver pine (Newnham *et al.* 1995). Silver pine would have been stunted shrubs to small trees, though would have formed a low forest with rimu and kahikatea on wetland margins.

Characteristic native fauna:

Pre-human era: There is little information on the pre-human fauna of these wetland ecosystems, but some of them were possibly used by Mantell's moa, which favoured wetlands and wetland margins (Tennyson & Martinson 2006). Birds that fed, nested or sheltered in these ecosystems could have included adzebill, flightless goose, swan, Australasian and little bitterns, various ducks, rails, snipe and

Image below: Mānuka, greater wire rush and tangle fern in a Tomarata wetland. **Jason Hosking.**



WL2 at Te Arai. **Brenda Osborne.**

passerines, especially fernbird (Atkinson & Millener 1991; Worthy & Holdaway 2002). Bird numbers and species composition would have fluctuated in some of these ecosystems in response to prehistoric fires, which would have opened up the habitat from time to time. Several gecko species, including green and forest geckos, were probably also present, especially in those wetland types with mānuka as a component.

Grey warbler. **Michael Anderson.**

Present: Fernbird, fantail, grey warbler and silvereye commonly occur in these ecosystems, and green and forest geckos occur where mānuka and tangle fern are present. Introduced birds include dunnock, chaffinch, blackbird and song thrush.

Key processes and interactions: Though these wetlands are mesotrophic, they are on the pathway to being oligotrophic bogs with time, accumulation of peat, reduction in nutrient availability and colonisation by bamboo rush (Clarkson *et al.* 2004), although this species is extinct in the Auckland region. They are highly flammable and were known to burn in pre-human times on a one-to-several-century cycle (Clarkson 1997). They often grade down-slope into *Machaerina* sedgeland-dominant communities (WL11) with a higher water table and fertility.

Threats: These wetlands have been greatly reduced in extent as a result of drainage and development for agriculture, primarily for dairy pastures.
Many were frequently burnt by Māori and Europeans, which may have on occasion resulted in the organic soils combusting as peat fires. Frequent fires are also likely to have exterminated slow growing, long lived woody species such as silver pine which have been recorded in pollen cores in these wetlands within the Waikato basin (Newnham & Lowe 1995).

WL2 at Tomarata. **Jason Hosking.**

The hydrology of most examples has been modified by perimeter drainage, leading to decomposition of soil organic matter.

The edges have higher fertility and are often dominated by weeds (e.g. grey willow, royal fern and blackberry). The dense structure of intact examples means that few weeds invade, though as they are highly flammable, invasion by ephemeral weeds occurs following fire (Clarkson 1997).
The greatest potential weed threat to this ecosystem, however, is from acid-loving ericaceous species, which have recently started to invade.
The fragile vegetation is highly vulnerable to damage by trampling, and if damaged is likely to be displaced by mānuka fen (WL12).

WL3

Bamboo rush, greater wire rush, restiad rushland

Regional IUCN threat status: **Collapse**

This ecosystem occupies ombrotrophic raised bogs of approximately >7000 years old in warm and sub-humid northern New Zealand (Clarkson *et al.* 2004). Soils are organic, poor-draining, highly acidic (<5 pH) and nutrient-poor (Molloy 1998; de Lange *et al.* 1999).

Distribution: Palustrine wetlands in Waikato lowland plains (e.g. Kopuatai, Moanatuatua) within raised bogs, though formerly occurred at Lake Tangonge in Northland (de Lange *et al.* 1999). Bamboo rush pollen and macrofossils have been found in peat bogs that once occurred between Papakura and Takanini, although they are no longer present (de Lange 1999). This ecosystem type has, therefore, 'Collapsed' in the Auckland region.

Characteristic native flora: This ecosystem is species-poor and is dominated by a few acid-tolerant species that are highly flammable. It is a restiad rushland with abundant bamboo rush and locally abundant greater wire rush, with occasional scrub of mānuka, gumland grass tree and Sinclair's tamingi, and, locally, *Lycopodiella lateralis*, *Machaerina teretifolia*, *Schoenus brevifolius* and tangle fern. It may include small embedded pools with sphagnum, bladderwort and sundew spp. (Campbell 1964; Clarkson 1997; de Lange *et al.* 1999).

Kopuatai wetland, Waikato. **Bev Clarkson.**

Image above: Gumland grass tree. **Peter de Lange.**

Characteristic native fauna:

Pre-human era: There is little information on the pre-human fauna of these wetland ecosystems, but some of them were possibly used by Mantell's moa, which favoured wetlands and wetland margins (Tennyson & Martinson 2006). Birds that fed, nested or sheltered in these ecosystems could have included adzebill, flightless goose, swan, Australasian and little bitterns, various ducks, rails, snipe and passerines, especially fernbird (Atkinson & Millener 1991; Worthy & Holdaway 2002). Bird numbers and species composition would have fluctuated in some of these ecosystems in response to prehistoric fires, which would have opened up the habitat from time to time. Several gecko species, including green and forest geckos, were probably also present, especially in those wetland types with mānuka as a component.

Present: Fernbirds commonly occur in these ecosystems, and green and forest geckos occur where mānuka and Sinclair's tamingi are present.

Key processes and interactions: The raised bogs form over many thousands of years within depressions (e.g. old river channels and shallow lakes) on flat landforms that were gradually in-filled through accumulation of sediment and peat (de Lange 1989). Over time, they are transformed, initially from swamps, to fens and then eventually to raised bogs. The accumulation of peat creates a raised profile and results in the system being entirely ombrotrophic (Clarkson *et al.* 2004). Prior to human arrival, natural fires occurred on a one-to-several-century cycle (Clarkson 1997). These fires were likely important disturbance processes that maintained early successional species (e.g. swamp helmet orchid) (Norton & de Lange 2003).

Threats: This ecosystem once occupied >100,000ha, but was eliminated from 95 per cent of its range by 1970 (including from Northland) and now only 3140 hectares remain (de Lange *et al.* 1999). This loss is largely due to drainage and land development for pastoral agriculture. It is now confined to Torehape, Kopuatai and Moanatuatua bogs, of which only Kopuatai is a fully functional, intact raised-bog ecosystem; Torehape and Moanatuatua are fragmented remnants of much larger examples and their water tables have been greatly modified. All three remaining examples are highly vulnerable to fire. There is good evidence to suggest that fires are necessary to maintain bamboo rush (and other associated species), but excessive burning could also eliminate it (de Lange 2005). This ecosystem is highly resilient to weed invasion, though acid-loving ericaceous species have recently invaded some areas.

Bamboo rush. **Jeremy Rolfe.**

WL10 Oioi, restiad rushland/ reedland

Regional IUCN threat status: Endangered

Oioi. **John Barkla.**

This ecosystem occupies mesotrophic wetlands within the freshwater zone of estuaries, and also shoreline wetlands of some inland lakes. Water table heights can fluctuate moderately, although they are often below the surface in summer. It occurs on a range of soils, including raw soils, lakeshore and estuarine silts, though over time peat accumulates, developing organic soils (Eser 1998; Deng *et al.* 2004).

Distribution: Riverine/lacustrine wetlands in North, South and Chatham Islands, occurring in freshwater areas of estuaries, coastal stream margins and in some inland areas adjacent to lakes (e.g. central North Island and Southland). Further survey is required to delineate this ecosystem type accurately in the Auckland region, but it is likely to be present at the mouths of many streams discharging into estuaries, on the coast or into lagoons, e.g. along the Waitākere coastline and on Great Barrier Island.

Characteristic native flora: Abundant oioi, locally with large *Machaerina* spp. and occasional pūrua grass, kuta and lake clubrush, often with scattered raupō and harakeke. Frequently grades up-slope into wetland scrub on the margins (Deng *et al.* 2004).

Characteristic native fauna:
Pre-human era: There is little information on the pre-human fauna of these wetland ecosystems, but some of them were possibly used by Mantell's moa, adzebill, flightless goose, swan, Australasian and little bitterns, various ducks, rails, snipe and passerines, especially fernbird (Atkinson & Millener 1991, Worthy & Holdaway 2002). Bird numbers and species composition would have fluctuated in some of these ecosystems in response to prehistoric fires, which would have opened up the habitat from time to time.

Present: Fernbird commonly occurs in this ecosystem along with locally, Australasian bittern, banded rail, spotless crake, marsh crake, pūkeko and harrier. Seasonally they are also used by tūī and bellbird (where present) when harakeke is in flower. Introduced fauna includes bell frog and mallard.

Key processes and interactions: This ecosystem primarily occurs in coastal and lowland areas, and near the coast it often grades into salt marsh. It is dominated by oioi, a highly competitive clonal species, and has many species in common with dune plains, *Machaerina* sedgelands and the salt-marsh component of estuaries.

Threats:
Owing to the dense clonal growth of oioi, this wetland type is moderately resilient to weed invasion, however grey willow (Eser 1998), Japanese walnut and Manchurian rice grass are capable of invading, and over time can transform areas into communities dominated by introduced species.

Image above: The brown teal / pateke is still common in coastal wetlands on Great Barrier. **Neil Fitzgerald Photography.**

Image right: Oioi, restiad rushland/reedland with new shoots of purua grass emerging in spring. **Jason Hosking.**

WL11 *Machaerina* sedgeland

Regional IUCN threat status: Critically Endangered

Jointed twig rush and kuta are common in this *Machaerina* sedgeland at Tunnel Point, Waitākere. **Jason Hosking.**

Machaerina sedgeland occupies mesotrophic wetlands in shallow depressions, and sheltered lake and lagoon margins, such as dune lakes that have moderately fluctuating water table heights and are occasionally dry. It occupies a range of soils, including raw sands and silts on lake margins; over time, peat accumulates and acid organic soils develop (Dobson 1979; Pegman & Ogden 2006).

Distribution: Palustrine/riverine/lacustrine wetlands throughout New Zealand, including cool montane areas. Common in the central North Island, but more restricted in the South Island (e.g. Kākāpō Mire). Examples on the margins of mesotrophic lakes include Lake Waikareiti and Lake Rotopounamu. Widely distributed throughout the Auckland region on the margins of most lakes and in shallow basins.

Pukeko are frequently found near sheltered fresh or brackish water including *Machaerina* sedgeland wetlands. **Rob Suisted/ www.naturespic.com**

Characteristic native flora: This ecosystem is dominated by sedgeland–rushland of a wide range of regional variants and includes species of *Machaerina, Lepidosperma, Eleocharis*, and, locally, lake clubrush, *Carex* spp. and scattered stunted harakeke. Regionally, individual wetlands tend to be dominated by a few species, with *M. teretifolia, M. rubiginosa* and square sedge more abundant on (lower-end) mesotrophic, acidic, organic soils (Burrows & Dobson 1972; Ogle & Barlett 1981; Clarkson 1984, 1997), while *M. arthrophylla*, kuta, sharp spiked sedge and lake clubrush are more abundant on raw soils on lake margins (Kapa & Clarkson 2009). It often grades into oioi and up-slope into tangle fern, wire rush (although this species is not common in the Auckland region), and locally *Gahnia* spp. or mānuka scrub fens.

Characteristic native fauna:
Pre-human era: There is little information on the pre-human fauna of these wetland ecosystems, but some of them were possibly used by Mantell's moa, which favoured wetlands and wetland margins (Tennyson & Martinson 2006). Birds that fed, nested or sheltered in these ecosystems could have included adzebill, flightless goose, swan, Australasian and little bitterns, various ducks, rails, snipe and passerines, especially fernbird (Atkinson & Millener 1991; Worthy & Holdaway 2002). Bird numbers and species composition would have fluctuated in some of these ecosystems in response to prehistoric fires, which would have opened up the habitat from time to time.

Present: Fernbird commonly occurs in these ecosystems, and green and forest geckos occur on margins where mānuka and tangle fern are present. They are also used by Australasian bittern, banded rail, spotless crake, pukeko, some waterfowl, harrier, kingfisher, grey warbler and fantail. Introduced fauna includes bell frog and mallard.

Key processes and interactions: This ecosystem generally forms dense near-monocultures in shallow basins and on lake and lagoon margins. It often occupies the lowest part of wetland complexes (with the highest water table) and receives nutrients from surrounding higher land. The wetlands are highly productive and accumulate large amounts of dry matter that form peat (Pegman and Ogden 2006).

Threats: This wetland type is highly vulnerable to invasion by a range of weeds, especially grey willow, which is capable of transforming areas into willow forest (Eser 1998). Lakeshore examples have also declined as a result of lake eutrophication and then invasion by species more suited to these conditions such as raupō and competitive weeds (e.g. floating sweetgrass).

Machaerina sedgeland. **Jason Hosking.**

WL12

Mānuka, tangle fern scrub/fernland [Mānuka fen]

Regional IUCN threat status: Critically Endangered

Mānuka, tangle fern scrub/fernland occupies mesotrophic (fen) wetlands, occurring in areas that are often seasonally wet and dry, such as the margins of lakes and the freshwater zone of estuaries. In larger wetlands it often occurs on the margin between forest and more permanently saturated fen (e.g. *Machaerina* sedgeland) or bog (e.g. wire rush) communities (Burrows & Dobson 1972).

Distribution: Palustrine wetlands throughout New Zealand, from Northland (e.g. Maitahi Scientific Reserve) and Central North Island (e.g. Paramanawera wetland, southern Ruapehu) to Southland; especially common on the West Coast.

Image below: Mānuka, tangle fern scrub/fernland at Omaha. **Jason Hosking.**

The most extensive remaining examples of this ecosystem type in the Auckland region occur in the wetlands of Great Barrier Island, with other examples including small remnants scattered along the South Head Peninsula and buffering the Omaha swamp forest.

Characteristic native flora: Occurring across most of New Zealand, this ecosystem type has a wide range of variants. It is characterised by scrub of abundant mānuka, with occasional species of *Coprosma* and *Dracophyllum*, and in cooler and higher-rainfall locations, one or more conifers, including bog pine, silver pine, pink pine and, locally, stunted rimu. Dominant sub-canopy plants include species of *Machaerina* and *Lepidosperma*, tangle fern, sphagnum and *Carex* spp., and, locally, *Schoenus pauciflorus* and species of *Gahnia* and Astelia (e.g. swamp astelia).

Characteristic native fauna:
Pre-human era: There is little information on the pre-human fauna of these wetland ecosystems, but some of them were possibly used by Mantell's moa, which favoured wetlands and wetland margins

Mānuka fen. **Jason Hosking.**

(Tennyson & Martinson 2006). Birds that fed, nested or sheltered in these ecosystems could have included adzebill, flightless goose, swan, Australasian and little bitterns, various ducks, rails, snipe and passerines, especially fernbird (Atkinson & Millener 1991; Worthy & Holdaway 2002). Bird numbers and species composition would have fluctuated in some of these ecosystems in response to prehistoric fires which would have opened up the habitat from time to time. Several gecko species, including green and forest geckos, were probably also present.

Present: Fernbird commonly occurs in these ecosystems, and green and forest geckos are also present. Modified areas and the more fertile margins, where introduced willows have invaded, provide habitats for Australasian bittern, banded rail, spotless crake, pūkeko, some waterfowl, harrier, kererū, shining cuckoo, kingfisher, fantail, grey warbler and silvereye. Introduced fauna includes bell frog, mallard, pheasant, dunnock, blackbird and song thrush.

Key processes and interactions: Scrub swamps occur on intermittently wet soils and often grade up-slope from *Machaerina* sedgelands in areas with a low fire frequency. Some examples are probably successional and will eventually develop into

Mānuka. **John Sawyer.**

Fernbirds occur in a range of wetlands and saltmarsh types, especially those with dense cover. **Geoff Moon.**

wetland forest that includes kahikatea, rimu and silver pine.

Threats: Large areas of this ecosystem type have undoubtedly been developed into pasture as they occur on soils that are often seasonally dry. Māori and European fires reduced the extent and abundance of mānuka-scrub swamps as they contain highly flammable vegetation. Remaining examples tend to be restricted areas with limited anthropogenic fire history, or they are small in size and occur in natural fire refugia. Mānuka-scrub swamps are vulnerable to invasion by weeds, including pampas and blackberry, along with lodgepole pine and alder in other parts of the country.

WL15 Herbfield [Lakeshore turf]

Regional IUCN threat status: Critically Endangered

Lakeshore turf on the margins of Lake Rototoa. **Jason Hosking.**

Herbfield (commonly known as lakeshore turf) or low mixed community (Johnson & Brooke 1998) occupies a narrow band of habitat on shallow-gradient, fluctuating lake shorelines, between permanent aquatic vegetation and taller lakeshore vegetation (often sedgeland or scrub communities) (Johnson 1972). This zone is an ephemeral wetland, experiencing periods of submergence when lake levels are high and exposure when lake levels are low, predominantly in summer– autumn. Soils are generally raw sand or fine gravels, though may contain silts, clays and humus. It is most extensive on lake edges with high seasonal water-height fluctuations and low fetch (Riis & Hawes 2003; Hawes *et al.* 2003). This ecosystem includes the nationally rare ecosystem 'Lake margins' (Williams *et al.* 2007).

There are two broad variants:

- WL15.1: Coastal.
- WL15.2: Inland.

Species are often common to both variants.

Distribution: Lacustrine wetlands associated with coastal (e.g. Lake Wairarapa and Lake Forsyth) and inland lakes (e.g. Lake Manapouri, Lake Te Anau, Lake Waikaremoana and Lake Taupo) in North, South and Chatham Islands. Knowledge of the distribution and extent of this ecosystem in the Auckland region is incomplete; however it is known to occur ephemerally on the margins of dune lakes where there is a gentle gradient, e.g. Lake Rototoa.

Characteristic native flora: A relatively species-diverse ecosystem type consisting of a tight herbfield to low sedgeland, with few species exceeding 20 mm in height (Johnson 1972). Coastal lakes are often brackish and commonly include half star, mudwort, clubrush and *Lilaeopsis novae-zelandiae*, and can grade into salt marsh with increasing salinity. The inland variant commonly includes *Glossostigma elatinoides*, *Lilaeopsis novae-zelandiae*, and species of *Carex*, *Eleocharis*, *Lobelia*, *Centrolepis*, *Centipeda*, *Ranunculus*, plantain, pennywort and water milfoil, along with other herbaceous species.

The extinct flightless goose occurred in open areas and probably grazed on lakeshore turf. **Te Papa. Artist: Paul Martinson.**

Characteristic native fauna:
Pre-human and present eras: Lakeshore turf habitats could have been used by both Mantell's and stout-legged moa (Tennyson & Martinson 2006), swan, flightless goose, various now-extinct duck species, rails including takahē, extinct waterhen and coot, along with the wide range of water birds that use these habitats today, such as paradise shelduck, grey and mallard ducks, grey and brown teal, shoveler, shags, herons, pūkeko and stilts.

Key processes and interactions: Lakeshore turf includes a wide range of species, each with their own tolerance of submergence and emergence (Johnson & Brooke 1989). Species range from those that are mostly aquatic (e.g. water milfoil and pondweed), to short-lived dryland species capable of reproducing while the shoreline is exposed (e.g. *Lachnagrostis* spp.) (Johnson 1972). This results in strong species zonation along the gradient of period of submergence. The zonation pattern may change from year to year as a result of changing lake levels. In extreme dry periods, turf vegetation may even die off. Most species flower and produce seed only while exposed.

Lakeshore turf is used by a wide range of wetland birds, including stilts and dabbling ducks; when exposed, it is grazed by geese and swans, which is likely to be beneficial because it reduces competition from larger plants as well as adding fertility (Champion *et al.* 2001). In pre-human times, large numbers of grazing waterfowl may have been important for maintaining lakeshore turf, as well as dispersing seed between lakes.

Threats: Lakeshore turfs have been reduced in extent, largely as a result of lake levels being kept artificially high for hydro-power generation (e.g. Lake Taupo) or lowered for flood protection (e.g. Lake Waikare). They have, however, developed around artificial dams that are used for municipal supply or irrigation (e.g. Lake Onslow, Otago) and have marked seasonal fluctuations in water table height. This ecosystem is reasonably resistant to weed invasion, though locally some species are a threat, including crack willow, mercer grass (Champion *et al.* 2001; Ogle 2003) and a wide range of herbaceous species (e.g. scarlet pimpernel, hawkbit and mouse-ear chickweed (Johnson & Rogers 2003). Lake eutrophication and koi carp are also threats because they both reduce water clarity, limiting the sunlight this ecosystem receives when it is submerged. Lake eutrophication can also further exacerbate the growth of introduced weeds. Stock access is also detrimental, causing turf damage and pugging.

Image above: *Glossostigma elatinoides*. **John Barkla.**

Image below: Lakeshore turf. **Jason Hosking.**

WL18 Flaxland

Regional IUCN threat status: Critically Endangered

A flaxland wetland buffering kahikatea swamp forest in the Wayby valley. **Jason Hosking.**

Flaxlands are swamps which occur on young landforms (Bagnall & Ogle 1981) that regularly flood or receive surface flow from surrounding land. They are most common adjacent to streams and rivers, lake edges and dune swales. Flaxlands are often summer-dry and typically have recent soils with high nutrient levels, though with increasing inundation and time, they accumulate organic matter.

Distribution: Palustrine/riverine/lacustrine wetlands from Northland to Southland, especially coastal and riparian wetlands (e.g. Taupo swamp, Plimmerton). Abundant on the West Coast from north-west Nelson (e.g. Mangarakau) to South Westland. Also present inland in cool districts, e.g. Waiouru and Canterbury (e.g. Lake Coleridge). Auckland examples include wetlands in the Wayby valley, Rodney, and small patches along the base of the cliffs at Whatipū adjacent to dune lakes.

Characteristic native flora: Flaxlands are often dominated by a small number of highly competitive species. They are typically characterised by abundant harakeke, often with toetoe, kiokio, species of *Carex* (e.g. pūkio), *Machaerina*, *Ranunculus* and *Epilobium*, and occasional wetland scrub and scattered treeland of cabbage tree, *Coprosma* spp., mānuka, and, locally, weeping matipo and ribbonwood (Johnson & Brooke 1998). In areas with a higher water table, they often intergrade down-slope into areas dominated by pūkio and raupō. Margins of flaxland often grade into wetland carr (fen overgrown with trees), with emergent cabbage trees, mānuka and scattered kahikatea. Occasionally these wetlands are dominated by cabbage trees, representing a later successional example of this ecosystem type.

Characteristic native fauna:

Pre-human era: Flaxland habitats could have been used by both Mantell's and stout-legged moa (Tennyson & Martinson 2006), various now-extinct duck species, rails including takahē, extinct waterhen and coot, Australasian and little bitterns, and fernbird. On the margins, fruiting kahikatea and cabbage trees would have attracted a range of frugivorous birds, including kākāpō, kākā, kererū, tūī, bellbird, saddleback, huia, kōkako and piopio. Nectivorous species, such as tūī, bellbird, hihi, saddleback and geckos would have fed on flax nectar in season.

Present: Flaxlands provide habitats for Australasian bittern, grey and mallard ducks, grey and brown teal, shoveler, banded rail, spotless crake, pūkeko, harrier and fernbird. On the mainland, flowering flax is visited by tūī, house sparrow, starling and myna.

Flax dominated wetland in the foreground with cabbage tree carr beyond. **Jason Hosking.**

At sites with few or no introduced predatory mammals, flax nectar is also taken by hihi, bellbird, saddleback and kōkako.

Key processes and interactions: Flaxlands occupy wetlands that are predominantly young and still receive nutrient inputs from flooding and surface flows from surrounding land. They are successional, and with time, may develop into mesotrophic fens as nutrient inputs decline and they accumulate organic matter, or sometimes cabbage-tree carr and eventually swamp forest (Esler 1978b; Sykes *et al.* 1991).

Threats: Flaxlands have been greatly reduced in extent through clearing for pasture, primarily because they occur on flat and fertile land. In many regions and districts that formerly contained large areas of flaxland (e.g. Northland), only small fragments remain (Coning 2001). Historically, many examples were harvested for flax fibre and their water tables were lowered to enhance flax growth. In lowland areas, remaining flaxlands are often small and fragmented, and have modified water tables with enhanced fertility from agricultural run-off.

This often results in proliferation of species such as water pepper, water celery, *Carex* spp. and *Isolepis prolifer*. However, extensive flaxlands remain in good condition on the west coast of the South Island and locally elsewhere. Flaxlands are colonised by a wide range of weeds, many of which are transformer species, such as willows and alder, capable of displacing a large number of other species.

Flax provides an important source of nectar for tui. **Neil Fitzgerald Photography.**

WL19 Raupō reedland

Regional IUCN threat status: Endangered

Little Shoal Bay raupō reedland, North Shore. **Alastair Jamieson.**

Raupō reedland occurs on the margins of lakes, lagoons, ponds and river oxbows, and in flooded valleys. They are generally marshes with mineral soils and a widely fluctuating water table, though often grade into swamps with peat soils (Ogden & Caithness 1981; Pegman and Ogden 2005). They are most common in coastal regions, especially eutrophic lakes, such as oxbow meanders, dune lakes and coastal barrier lakes. Raupō reedlands can be summer-dry, generally on recent mineral soils with high nutrient levels, though with time these accumulate peat.

Distribution: Palustrine/riverine/lacustrine wetlands from Northland to South Otago (e.g. Lake Waihola), occurring within warm to cool climates. Widespread throughout the Auckland region, the largest and best known examples include Te Henga swamp on the mainland and Kaitoke Swamp on Great Barrier Island. Particularly common on farms as small patches in gullies, however many of these have replaced the original forest ecosystems on those sites.

Characteristic native flora: This ecosystem type is dominated by abundant raupō, locally with species of pūrua grass, lake clubrush, jointed twig rush, toetoe, pūkio and harakeke. In northern New Zealand, swamp millet can be abundant, especially where raupō reedlands merge with flaxlands. In areas of shallow water, it includes floating or rafted aquatics, such as water milfoils, *Ranunculus* spp, willowherbs, pondweed, clubrush, azolla, duckweed and *Eleocharis* spp. (e.g. kuta). Raupō reedland often grades up-slope into flaxland (WL18) and/or *Coprosma*-dominated scrub, locally with mānuka, cabbage trees and scattered kahikatea on wetland margins.

Spotless crake. **Neil Fitzgerald Photography.**

Characteristic native fauna:

Pre-human era: Raupō reedland habitats could have been used by Mantell's moa, which occurred around wetlands (Tennyson & Martinson 2006), swan, flightless goose, various now-extinct duck species, grebes, rails including takahē, extinct waterhen and coot, Australasian and little bitterns and fernbird. On the margins, fruiting kahikatea and *Coprosma* spp. would have attracted a range of frugivorous birds, including kākāpō, kākā, kererū, tūī, bellbird, saddleback, huia, kōkako and piopio. Insectivores in woody vegetation along the margins could have included tuatara, skinks, geckos, small rails, snipe, owls, owlet-nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

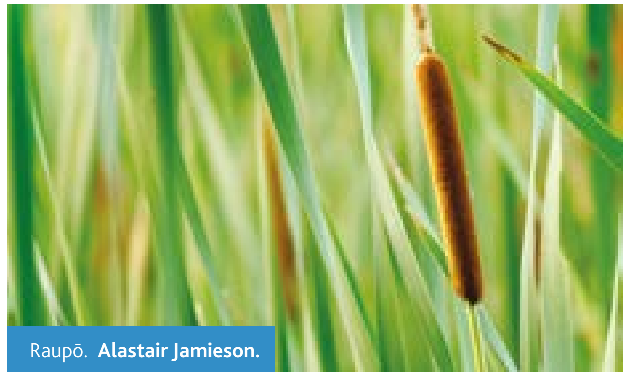
Raupō reedland at the base of Waimaru Bush, Takatu Peninsula. **Alastair Jamieson.**

Present: Raupō reedlands provide habitat for dabchick, black swan, paradise shelduck, grey and mallard duck, grey and brown teal, shoveler, Australasian bittern, white-faced heron, banded rail, spotless crake, pūkeko, harrier and fernbird. Woody vegetation along the margins have a range of native and introduced birds, including kererū, kingfisher, shining cuckoo, fernbird, fantail, grey warbler, tui, silvereye, blackbird, dunnock and chaffinch. Two species of introduced bell frog may be present.

Key processes and interactions: Raupō is a highly competitive, fast-growing species well adapted to lakeside marsh habitats and valley-floor swamps, often dominating the communities it occurs within. In spring through to late summer, it produces abundant tall foliage that may exceed 3m in height. From late autumn, this foliage dies down and the plant rests over winter as subterranean rhizomes. Raupō produces a large amount of above- and below-ground biomass that traps sediment; it builds peat and facilitates the colonisation by swamp species such as harakeke (Ogden & Caithness 1981). It produces minute, spore-sized seeds, making it capable of colonising over vast distances, either via wind or attached to waterfowl, and it is frequently a primary coloniser around constructed dams and farm ponds, though these examples tend to be floristically poor.

Threats: Forest clearance by pre-European settlers increased flooding, sedimentation and eutrophication of formerly mesotrophic fen wetlands, resulting in an expansion in extent of raupō reedlands (McGlone 2009). European agriculture exacerbated this, further increasing nutrients within wetlands, as evidenced at Pukepuke Lagoon, Manawatu (Ogden & Caithness 1981). Eutrophication increases the vigour and abundance of raupō, though it is likely also detrimental to many subordinate species in this ecosystem (Cooke *et al.* 1990). Confounding this increase in vigour and abundance is that the overall area of raupō reedlands has likely reduced as a result of wetland drainage. Stock grazing also causes considerable damage in dry periods.

Raupō reedlands occupying areas with a high fluctuation in the water table are comparatively resilient to invasion by common wetland weeds such as grey and crack willows (Eser 1998). Weeds capable of invading and dominating include Manchurian rice grass, reed canary grass, floating sweetgrass and alligator weed. Raupō reedlands often contain numerous subordinate invasive weeds such as water purslane, water speedwell, water celery and beggars' ticks.



Raupō. **Alastair Jamieson.**

Coastal saline ecosystems

Coastal saline ecosystems occupy a niche at the interface between land and sea. Ecosystem patterns and biodiversity are driven by strong environmental gradients in salinity, substrate and hydrodynamics (including tidal variation, sediment supply, wave action and sea spray).

Auckland's diverse coastline, with its rocky headlands, estuaries, tidal inlets and expansive harbours, provides considerable variability in environmental (abiotic) factors, which result in a range of coastal saline ecosystem types. These include both common ecosystem types (e.g. mangrove forest) and naturally uncommon types, such as shore bindweed, knobby clubrush gravel/stonefield beaches (SA4). Four coastal saline ecosystems types are recognised in the Auckland region.

Mangrove forest and scrub (SA1) occurs on estuarine mudflats, most commonly located in sheltered harbours and tidal inlets. This ecosystem is colonised by species that tolerate periodic inundation and salinity changes. A number of distinct variants exist within this type, including sea-grass swards at the lowest intertidal zone, to mangrove forest and scrub (mid to upper shore). These highly productive systems provide vital ecosystem services, such as buffering coastal erosion, providing habitat, sediment/contaminant retention and carbon sequestration. The native fauna associated with estuarine mudflats includes marine and terrestrial invertebrates, fin fish, and a wide range of bird species.

Mangrove forest and scrub has an overall threat classification of Least Concern, although components of this ecosystem type are threatened, e.g. the shell barrier beach variant, which is identified as a nationally rare ecosystem type. Mangrove forest and scrub can become modified over time in response to catchment management issues. Increased sedimentation from land clearance can reduce the diversity of ecosystem variants, for example, mangrove forest may become dominant to the detriment of other communities, such as sea-grass meadows or saline rushlands and herbfields. This may lead to a loss in biodiversity, despite an overall increase in the extent of the ecosystem type. Catchment management and sediment supply play an important role in the dynamics of this ecosystem type.

Herbfield [coastal turf] (SA5) usually develops on rocky promontories that are frequently subjected to salt spray, spume and frequent strong coastal winds. Predominantly found along Auckland's west coast and offshore islands, coastal turf ecosystems are species-rich, with a specialised range of herbs, sedges and grasses able to colonise this challenging niche. Seabirds and marine mammals roost and breed in these areas. Their physical disturbance and nutrient inputs halt succession to woody species and help to maintain diversity and viability in this ecosystem type. These ecosystem processes are much reduced due to historic declines in coastal wildlife.

Similarly, disturbance has an essential role in maintaining diversity of other coastal saline ecosystems. Seabirds have created the iceplant, glasswort herbfield/loamfield ecosystem type (SA7) in areas that would, in their absence, revert to coastal forest. Coastal saline ecosystem types illustrate the importance of protecting and enhancing the complex interactions between ecosystem components, of which some marine wildlife are keystone species.

The range of flora and fauna within coastal saline ecosystems makes them some of the most diverse in the Auckland region. However, their coastal location and vulnerability mean there are significant management and conservation challenges as Auckland continues to grow.

Image left: Shell barrier beaches, salt marsh, intertidal mudflats and mangroves of Pollen Island in the upper Waitematā Harbour. **Alastair Jamieson.**

SA1

Mangrove forest and scrub

Regional IUCN threat status: Least Concern*

Whangapoua estuarine ecosystem in the foreground and the dunes of Whangapoua beach in the distance, Great Barrier Island. **Alastair Jamieson.**

This variable ecosystem occupies frost-free estuarine systems to mean low-water springs (within tidal estuaries, inlets, rivers and streams) and is associated with tides with salinity >5 per cent (Johnson & Gerbeaux 2004). Salinity may vary greatly depending on salt and freshwater input and dilution. Hypersaline conditions occur in areas where salt water may inundate depressions during high tides, then subsequently evaporates. Soils are sulphuric gley and recent gley, locally with shell and/or gravel barrier beaches (Molloy 1998).

There are seven variants:

- SA1.1: A monoculture of sea grass occurring on low-lying mud or sandy silt flats where tidal inundation is longest.
- SA1.2: Mangrove forest and scrub occurring in areas of frequent tidal inundation with abundant silt deposition, particularly near stream and river mouths.
- SA1.3: Sea rush occurring in the upper estuarine zone where saltwater dilution is greatest. This generally merges upslope with oioi, locally swamp twig rush, and occasional salt marsh ribbonwood (Deng *et al.* 2004).
- SA1.4: Herbfield of glasswort, sea primrose, half star, shore celery, arrow grass and sea blite occurring usually as a mosaic among sea rush, in depressions where salt water pools evaporate, creating hypersaline conditions.
- SA1.5: Shell barrier beaches develop in some estuaries as long narrow ridges, which build up from wave-driven accumulations of dead mollusc shells and sand. Vegetation is often sparse, with scattered herbfield of glasswort, coastal needle grass, knobby clubrush, sea rush, sea primrose, bachelor's button and sea blite, and on the highest ground, occasional oioi, salt-marsh ribbonwood and tauhinu (Ward 1967).
- SA1.6: Scrub or low forest of salt-marsh ribbonwood, harakeke, coastal tree daisy and, locally, ngaio, kōwhai, mānuka and cabbage trees on low mounds and estuarine margins.
- SA1.7: Oioi-coastal needle grass on saline margins of lava flows (e.g. Anns Creek, Rangitoto Island).

* The regional threat status of individual variants has not been assessed, but it is worth noting that locally, this ecosystem may contain the historically rare ecosystems 'Shell barrier beaches' and 'Estuaries' (Williams *et al.* 2007), and other variants may be threatened.

Distribution: North of 38°S latitude from Raglan and Ohiwa. In the Auckland region, widely distributed throughout the region's harbours and estuaries. The best areas of sea grass occur in the Kaipara Harbour and the best shell barrier beaches in the Waitematā, Manukau and Kaipara Harbours along with Okura and Weiti estuaries.

Characteristic native flora: This ecosystem has at least seven species-poor but distinct communities along a zone of tidal inundation (as described above).

Characteristic native fauna:
Pre-human era: There is little information on what fauna might have formerly occurred in mangrove forest and scrub, However, this ecosystem, in addition to the native species we still see today, could have been used by a number of now-extinct birds that would have come from adjacent terrestrial habitats. These species could have included the stout-legged moa, adzebill and flightless goose, which occurred in coastal and open habitats (Tennyson & Martinson 2006), as well as swan, various ducks, rails, snipe and passerines. Insectivores could have included small rails, owls, whitehead, fernbird, fantail, grey warbler, saddleback and bats.

Present: This ecosystem, which contains a mosaic of different habitats, supports a wide range of bird species, including shags, herons, spoonbill, waterfowl, banded rail, marsh crake, pūkeko, migratory and New Zealand-resident shorebirds and kingfisher, which feed primarily on fish and invertebrates. Native and introduced passerines are also present, such as fernbird, fantail, grey warbler, silvereye, blackbird and finches.

Key processes and interactions: This ecosystem contains up to seven distinct communities, largely related to the duration of tidal inundation, elevation and salinity (Ward 1967; Deng *et al.* 2004). Sea grass within estuaries is important for capturing and stabilising sediment, buffering the estuarine environment from wave damage, nutrient cycling and increasing productivity. It provides foraging habitats for swans and a wide range of non-migratory and migratory wading birds, and is a nursery for various species of fish (Turner & Schwarz 2006).

Banded rail. **Neil Fitzgerald Photography.**

Threats: The major threats to this ecosystem are primarily abiotic and include eutrophication and increased sedimentation rates as a result of changing land use in surrounding catchments. Increased sedimentation has resulted in a decline of sea grass and caused an expansion of mangrove communities. Pollution and reclamation also threaten this ecosystem near urban areas and farmland, often leading to a proliferation of marine algae such as sea lettuce. While reclamation is less extensive than in the past, direct mangrove clearance near urban communities is an increasing threat. Stock grazing and trampling, especially by cattle, are major threats where unfenced farmland adjoins this ecosystem. The halophytic conditions mean there are few invasive weeds; however, several salt-tolerant grasses (e.g. sickle grass, cordgrass, saltwater paspalum and sea couch) can over-top and displace indigenous salt-marsh vegetation and wading-bird habitat (Partridge 1987; Shaw & Allen 2003). Invasive introduced invertebrates such as the Pacific oyster have also become abundant, growing on mangrove trunks and pneumatophores, as well as open areas of mudflats.

Shell barrier beach in the Okura estuary. **Jason Hosking.**

SA4

Shore-bindweed, knobby clubrush-gravelfield/stonefield

Regional IUCN threat status: Endangered

This ecosystem is associated with prograding gravel and boulder beaches, and also occurs within accreting estuarine areas with large rivers (e.g. Whakatīwai, Miranda).

Gravel and boulder beaches form where there is an ample supply of gravel and boulders (generally from large swift-flowing rivers), which in combination with coastal currents and landforms create a prograding coastline. They are common near river mouths in bays (e.g. Wairau River, Cloudy Bay), adjacent to coastal headlands (e.g. Kaitorete Spit), beneath coastal cliffs derived from or containing hard rock (e.g. Taranaki) and on islands where the prevailing current moves sediment to one shoreline (e.g. Kapiti Island) (Molloy & Smith 2002).

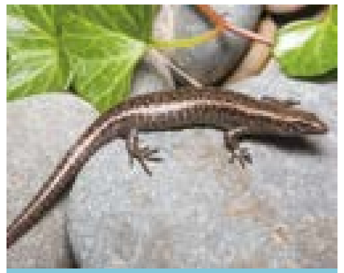
On the shore, coastal processes sort grain size so that smaller grains are deposited further up the beach (Morton 2004). This can eventually create a beach ridge or a series of ridges, or a plain of pebbles to cobbles. Soils are initially thin and raw (Molloy 1998; Williams *et al.* 2007) and extremely free-draining, with very little organic matter, which is mostly derived from decomposed humus (e.g. driftwood and seaweed). This results in extended periods of moisture deficit, especially in sub-humid and semi-arid climates. With a cover of vegetation, organic matter and windblown sediments accumulate and form soil. Being coastal, gravel and boulder beaches experience high amounts of salt spray.

This ecosystem includes the historically rare ecosystem 'Shingle beaches and stony beach ridges' (Williams *et al.* 2007)

Distribution: Most common in the South Island: Southland, Canterbury–Marlborough and West Coast. Very local in the North Island, occurring in Wellington, Hawke's Bay, Taranaki and Coromandel–Firth of Thames. Small isolated examples elsewhere including the Chatham Islands. Knowledge of the distribution of this ecosystem type in the Auckland region is incomplete; however it is found at Matingarahi, Tapapakanga, and on Waiheke and Little Barrier Islands.

Characteristic native flora: A process of natural succession occurs on prograding gravel and boulder-beach coastlines. The youngest areas closest to the coast have stonefield/gravelfield communities and older areas further inland grade into shrubland and treeland. There are at least four variants distributed nationally which are primarily related to mean annual temperature and moisture deficit (Wiser *et al.* 2010). Species include glasswort, half star, shore celery, arrow grass, shore spurge, knobby clubrush and shore bindweed, grading into coastal scrub–vineland that includes *Coprosma* spp., pōhuehue and, locally, *Melicytus* and *Ozothamnus* spp. and New Zealand daphne. Further inland, on older beach ridges, treeland may include ngaio, taupata, akeake, karo, wharangi, kōwhai, tānekaha and pōhutukawa.

Characteristic native fauna:



Shore skink. **Dylan van Winkel.**

Pre-human era: There is little information on what fauna might have occurred in this ecosystem in pre-human times, however in addition to the species we still see today, it could have been used by a number of now-extinct birds, including several species of moa, adzebill, flightless goose, various ducks, rails (including weka, waterhen and takahē), snipe and passerines including the North Island raven. Geckos and skinks would have been abundant in the boulder banks. Open gravel and boulder fields would have been used as haul-outs for sea mammals including the New Zealand fur seal and possibly the locally extinct New Zealand sealion, and also by nesting shorebirds, such as New Zealand dotterels and variable oystercatchers. Shore plovers, now extinct on the mainland, would have nested around the edges of the boulder fields, concealing their nests beneath low, fringing vegetation. Insectivores in areas of treeland further inland could have included tuatara, skinks, geckos, small rails, snipe, owls, owlet nightjar, wrens, robin, tomtit, whitehead, fantail, grey warbler, saddleback, huia, piopio and bats (Atkinson & Millener 1991; Worthy & Holdaway 2002).

Present: This ecosystem provides roosting and nesting habitats for migratory and New Zealand-resident shorebirds, and also habitat for kingfisher, and native and introduced passerines, such as pipit, fernbird, fantail, grey warbler, silvereye, finches and blackbird. Owing to weed invasion by gorse, fennel and blackberry, little open boulderfield nesting habitat for shorebirds remains, however coastal boulder banks with good all-round visibility and free of most vegetation, provide excellent high-tide shorebird roosts. Surviving reptiles include small numbers of skinks and geckos.

Key processes and interactions: The key processes for the existence of this ecosystem are the landform, the raw soil and high salinity; these processes facilitate vegetation succession of species tolerant of these conditions. In pre-human times, this ecosystem probably provided nesting habitat for a wide range of sea and shorebirds.

Threats: Very little woody vegetation on older gravel and boulder-beach landforms survived pre-European and European fires, being transformed into non-forest communities. Most examples on mainland New Zealand have suffered from a multitude of threats, although some highly intact examples occur on offshore islands (e.g. Kapiti and Little Barrier Islands).

This ecosystem has been reduced in extent and condition by a wide range of threats, including weeds, animal pests, grazing, vehicle damage, land development for housing and locally, viticulture. Weeds are particularly threatening, and Wiser *et al.* (2010) identified that up to 50 per cent of the flora is introduced species. Of particular threat are drought-tolerant leguminous herbs, shrubs and trees (e.g. lupins and gorse), which rapidly fix nitrogen and modify natural succession.

Intact shrubland and treeland stages are extremely rare and threatened. As there are so few examples of woody communities left on older gravel and boulder beaches, very little is known of their original composition.

Image above: Te Maraeroa boulder field at Te Titoki Point, Hauturu/Little Barrier Island. **Alastair Jamieson.**

Image left: Pōhuehue on a gravel beach near Matingarahi. **Jason Hosking.**

SA5

Herbfield [Coastal turf]

Regional IUCN threat status: Critically Endangered

Coastal turf on the south Muriwai coastline. **Jason Hosking.**

Herbfield, commonly known as coastal turf, occurs where persistent salt-laden winds prevent any vegetation taller than about 50mm from becoming established. It occupies coastal promontories of hard rock and, infrequently, consolidated sand and gravel. Soils contain high concentrations of soluble salts (Rogers & Wiser 2010).

This ecosystem includes the historically rare ecosystem 'Coastal turf' (Williams *et al.* 2007).

Distribution: Most common and well developed on coastlines of Taranaki–Wanganui, Te Tai Tapu–Nelson, north Westland, Otago, Southland, Fiordland and the Chatham Islands (Rogers 1999; Rogers & Wiser 2010). In the Auckland region, there are small patches of coastal turf along the south Muriwai to Waitākere coastline, on the north-eastern coast of Great Barrier Island (Wright & Cameron 1985), and on other Hauraki Gulf islands. Further survey work is required to determine the full extent of this ecosystem type in the region.

Coastal turf with abundant half star.
Jason Hosking.

Characteristic native flora: This is a highly diverse ecosystem type in relation to its spatial extent, with at least 139 indigenous species being recorded (Rogers & Wiser 2010). It is dominated by a wide range of halophytic herbs, sedges and grasses. Characteristic species include half star, sea primrose, shore celery, zoysia, slender clubrush, centella, *Hydrocotyle novae-zeelandiae*, and species of *Leptinella*, *Crassula*, *Nertera,* buttercup, forget-me-not, willowherb and sand musk. Auckland examples may also include glasswort, dichondra, *Lilaeopsis*, New Zealand iceplant and shore groundsel.

Characteristic native fauna:
Pre-human era: There is little information on what fauna might have occurred in this ecosystem in pre-human times; however it was probably used by a range of mainly coastal birds, including a number of now-extinct species. It could have been grazed by moa, extinct swans and geese, as well as forming open nesting habitats for coastal birds such as gannets, shags, gulls, terns and some waders. The extinct raven was probably also present. The soil was very fertile because of the nutrients the birds brought ashore (Atkinson & Millener 1991; Smith *et al.* 2011). The coastal turf would have been kept open and low by the effects of salt spray, seals hauling out, and the effects of grazing and nesting birds. Shore and Suter's skinks and some geckos were probably common where there was suitable cover.

Present: Coastal turf areas are used by roosting shags and shorebirds, and also by nesting white-fronted terns, and black-backed and red-billed gulls. Gannets also nest in places where this ecosystem occurs, however they are very destructive, and any herbfields within easy reach of their nests soon become bare. Native and introduced passerines include pipit, blackbird, starling and myna.

Key processes and interactions: Coastal turf is a very geographically restricted but highly distinctive ecosystem, primarily a result of frequent strong, salt-laden winds. In pre-human times, coastal turfs could have been used by a number of herbivorous birds, as well as being resting and haul-out sites for seabirds and seals. These birds and mammals may have helped to develop and enhance areas of coastal turf through grazing, physical disturbance and increased nutrients from faeces (Rogers & Wiser 2010).

Threats: The loss of associated fauna such as seals and coastal seabirds probably resulted in a decline of this ecosystem during the Māori and early European periods, when it was succeeded by taller vegetation. As a consequence, remaining areas of coastal turf occur in the most windy and exposed locations, which are unfavourable for taller vegetation. Where seabirds and seals are now absent, succession to taller vegetation may occur.

Many coastal turfs occur on private land, and most people are unaware of the conservation values of this ecosystem type. Turfs on isolated public conservation land (e.g. in Fiordland) have few if any immediate threats, and may be benefitting from periodic deer grazing. Coastal turfs in more-developed regions have a wider range of threats. Grazing by sheep and light grazing by cattle may be beneficial, but heavy grazing by cattle, causing turf damage and pugging, is detrimental. Weeds are a significant long-term threat, especially from salt-tolerant herbaceous species, such as plantain, lotus and some introduced grasses.

Coastal turf south of Piha. Jason Hosking.

SA7

Iceplant, glasswort herbfield/loamfield

Regional IUCN threat status: Critically Endangered

Seabird burrow. **Tracey Parsons.**

This is an ecosystem of coastal warm to mild areas, strongly influenced by salinity in association with physical disturbance and guano from seabirds. It is colloquially known in Northland–Auckland as 'petrel scrub' (Wright 1980).

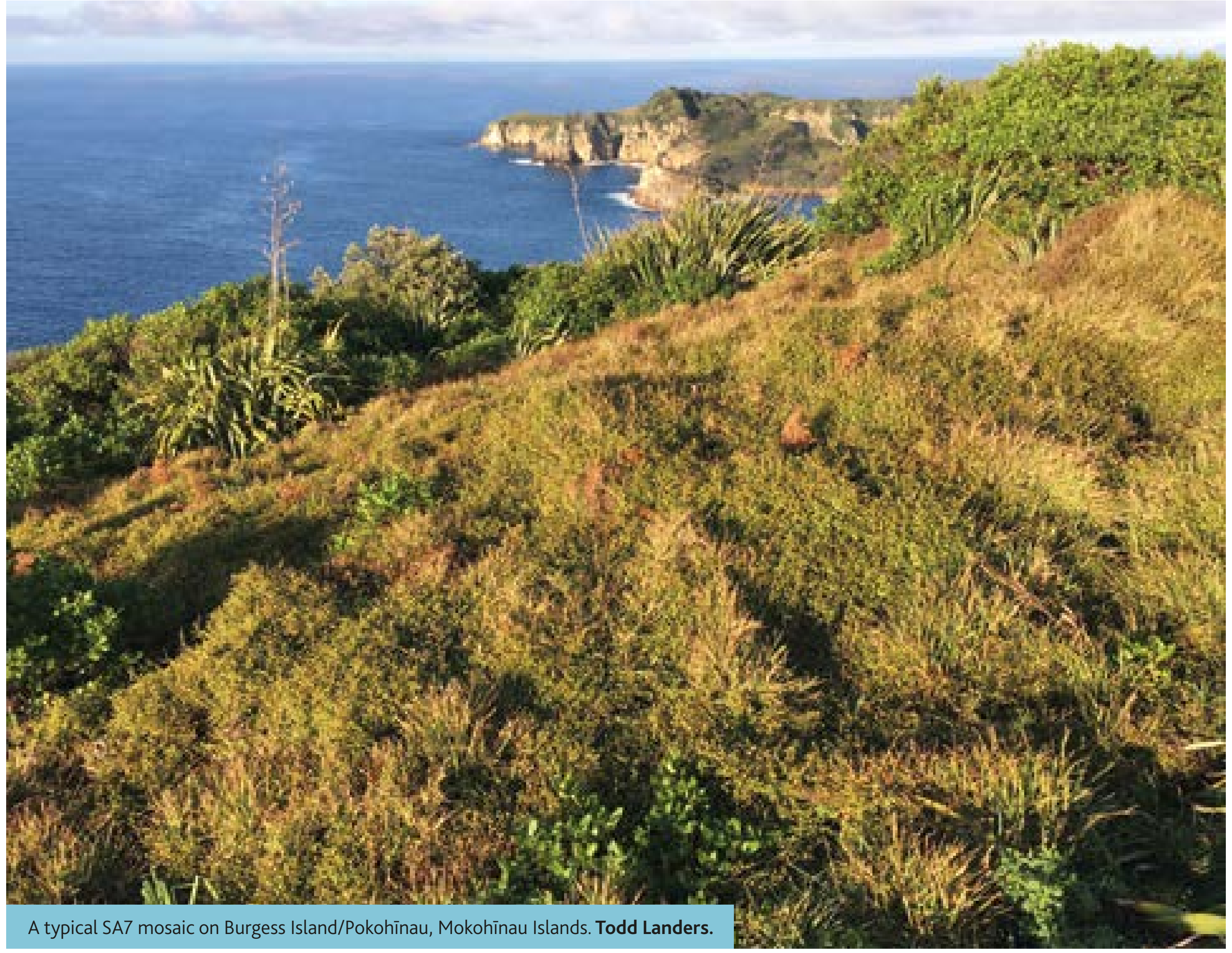
It includes the rare ecosystem 'Seabird burrowed soil and locally seabird guano deposits' (Williams *et al.* 2007).

Distribution: Formerly widespread on suitable coastal sites throughout mainland New Zealand from Northland to Otago, associated primarily with burrowing seabird colonies and abundant surface-nesting seabirds in exposed locations. It is now largely restricted to predator-free offshore islands. A good example of this rare ecosystem type in the Auckland region occurs on the Mokohīnau Islands.

Characteristic native flora: A mosaic of herbfield, including glasswort, iceplant, pigweed, shore groundsel, sea primrose, New Zealand celery and cress, scurvy grass; locally, poa species with scattered scrub–vineland of taupata, houpara, harakeke, ngaio, *Melicytus* spp., hebe and small-leaved pōhuehue, toetoe, oioi and knobby clubrush. This is interspersed with bare ground, bird burrows and guano deposits.

Characteristic native fauna:
Pre-human era and present: On islands free of predatory mammals, the fauna of iceplant–glasswort herbfield/loamfield ecosystems is probably quite similar to that which existed in pre-human times. On restored islands where pest mammals have been removed, the fauna characteristic of these ecosystems has begun to recover.

The soil is very fertile because of the nutrients the seabirds bring ashore (Atkinson & Millener 1991; Smith *et al.* 2011), and this supports abundant invertebrate and reptile populations. Seabirds include a range of petrel and shearwater species, such as diving petrel, little and fluttering shearwaters, white-faced storm petrel and grey-faced petrel. Surface-breeding seabirds include gannet, black-backed and red-billed gulls, and white-fronted tern. Reptiles include tuatara, geckos and skinks. Native and introduced passerines include pipit, blackbird, starling and myna.



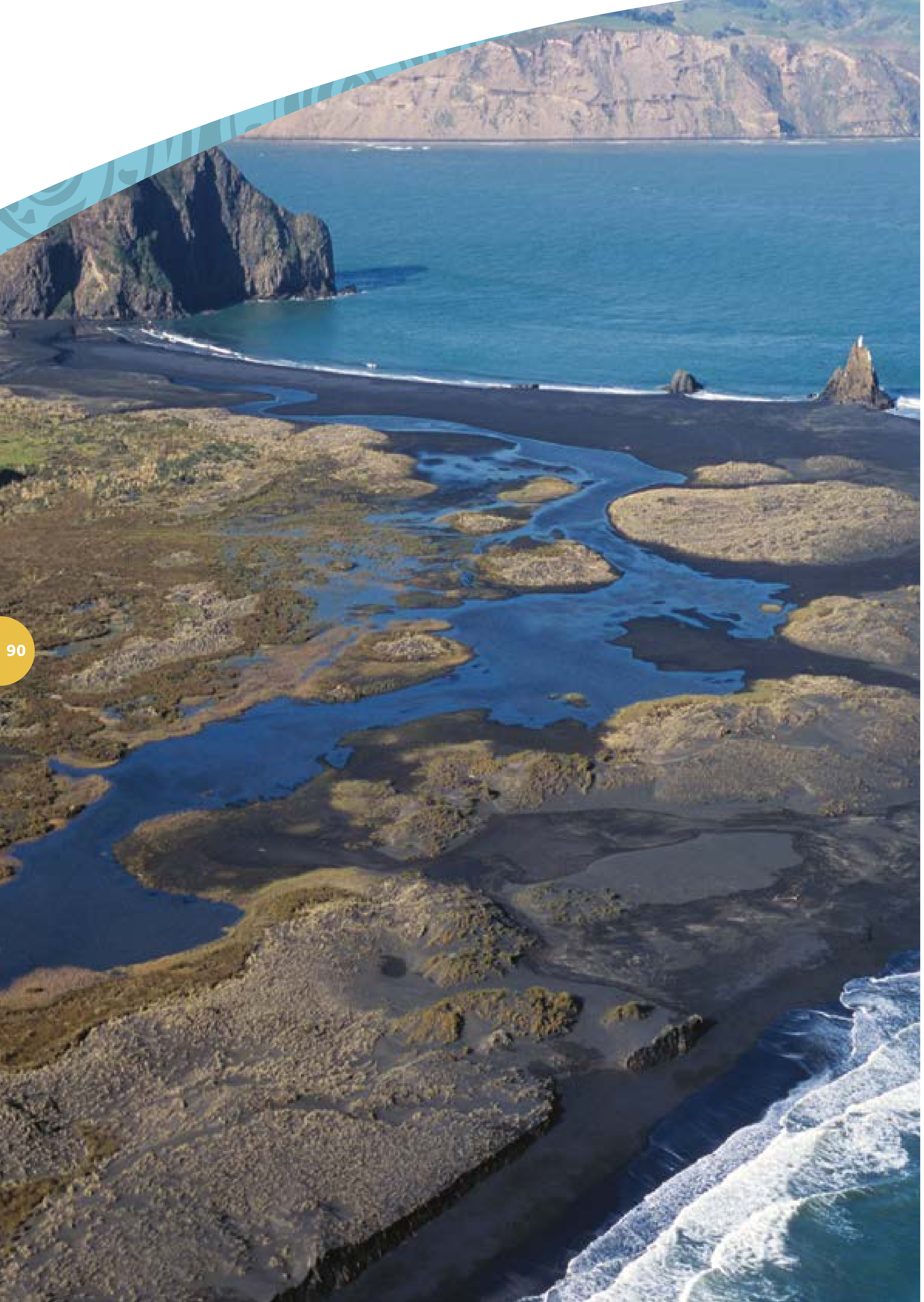
A typical SA7 mosaic on Burgess Island/Pokohīnau, Mokohīnau Islands. **Todd Landers.**

Grey-faced petrel at burrow entrance. **Tim Lovegrove.**

Key processes and interactions: In the absence of abundant burrowing seabirds, areas where this ecosystem occurs would likely be dominated by coastal forest trees or scrub. Large numbers of seabirds disturb vegetation, arrest succession, destabilise soils and increase fertility, enhancing ecosystem productivity (Atkinson 1985b, Jones *et al*. 2008). The result is a mosaic of communities, including bare ground with bird burrows, guano deposits and vegetated areas dominated by early successional, predominantly herbaceous halophytic species and scattered, disturbance-tolerant shrubs and vines. These communities have high numbers of invertebrates which in turn support abundant reptile faunas (Towns *et al.* 2009).

Threats: The most significant threat is from introduced predatory mammals, especially rats, which have exterminated or suppressed seabird populations (Jones *et al.* 2008). As a consequence, this distinctive fauna-derived ecosystem has become locally extinct from mainland New Zealand and many offshore islands. Recent eradication of rats from some offshore islands (Towns & Broome 2003) may allow some examples to recover or to be restored. Declining seabird populations caused by fisheries by-catch and plastic pollution in the marine environment are additional threats.

These ecosystems are also highly vulnerable to invasion by a large number of nitrophilous, predominantly herbaceous introduced weed species.



Dune ecosystems

Dune ecosystems occur immediately landward of sandy beaches, where wind-blown sand is captured by vegetation to form sand accumulations. These dynamic ecosystems clearly demonstrate the complex interaction between the abiotic and biotic factors, that shape biodiversity and ecosystem patterns along our coastline.

Foredunes develop as grass and sedge species trap wind-blown sand, with the different species present influencing dune topography (Esler 1970). This process advances in a seaward direction over time, resulting in a series of dunes, which stabilise as vegetation cover and diversity increases, ultimately developing into coastal forest.

Dune ecosystems display a succession of vegetation types that span a gradient from the tide line extending inland. Coastal foredunes occupy the seaward edge of these ecosystems, and are typically species-poor grass and sedgelands consisting of one or two dominant species (spinifex and pīngao). Over time, behind the immediate foredune, a range of other species colonise such as tauhinu, sand daphne and sand coprosma, as well as knobby clubrush, flax, bracken and eventually seral trees such as kānuka.

In the lee of foredunes, dune plains may also develop where dunes have eroded and moved down to the water table. This process creates a varied hummocky topography with wetland depressions called 'dune slacks', often separated by small sand ridges. Dune slacks allow increased species diversity and support additional sedge and restiad species like oioi and knobby clubrush, as well as a number of herbaceous coastal plants.

Two dune ecosystem types occur in Auckland: spinifex, pīngao grassland/sedgeland (DN2) and oioi, knobby clubrush sedgeland (DN5). Dune ecosystems provide habitats for a number of threatened plant species, e.g. pīngao, sand tussock and sand sedge. They also provide habitats for native fauna. Shorebirds such as New Zealand dotterel and variable oystercatcher often nest in the sparsely vegetated foredunes and open dune plains where good visibility allows the birds to see approaching predators. Terrestrial invertebrates include the increasingly rare native katipo spider, which inhabits coastal dunes.

Historically, dunelands have been modified by the planting of introduced species, such as marram, tree lupin and wattles to stabilise the sand to allow for grazing, seaside developments or forestry. Dune ecosystems are under threat from increasing coastal development, particularly near Auckland, where coastal land is at a premium.

Image left: Whatipū - one of Auckland's most extensive dune ecosystems. **Alastair Jamieson.**

DN2 Spinifex, pīngao grassland/ sedgeland

Regional IUCN threat status: Endangered

Pīngao. **Rebecca Stanley.**

Active dunelands develop where there is an abundant supply of wind-blown sand. They include a wide range of forms, from a simple vegetated ridge behind a beach to dune systems that extend inland for many kilometres. Dunes experience periodic drought, high surface temperatures, salt winds, sand-blasting and low nutrient availability (Hesp 2000).

They may be mobile as a result of disturbance, or when sand supply exceeds the capacity of plants to contain it (Muckersie & Shepherd 1995). Mobile dunes move inland with the prevailing wind, smothering vegetation and creating a new dune succession.

This ecosystem includes the nationally rare ecosystem 'Active sand dunes' (Williams *et al.* 2007).

Distribution: Spinifex, pīngao grassland/sedgeland occurs within the warm to mild coastal dunelands from Northland to Farewell Spit. Historically, it was scattered further south to the Buller River (West Coast) and to the Waimakariri River in the east, where spinifex reaches its southern limit. In Auckland, dunes are common on the western and north-eastern coastlines and on the east coast of Great Barrier Island. Karekare, Pākiri and Whangapoua are good examples of this ecosystem type.

Characteristic native flora:
Dunelands are naturally species-poor, occupied by a small group of highly specialised, drought-tolerant plants that capture sand and build dunes (Esler 1970). At the strand line, Holloway's crystalwort and sand sedge may occur, though the former is now restricted to the Far North and is threatened (de Lange *et al.* 2000). On an accreting shoreline, pioneer dune-building plants include spinifex and pīngao, locally with sand tussock and shore bindweed and, further inland, sand coprosma, tauhinu, sand daphne and small-leaved pōhuehue. With vegetation succession, active dunes become increasingly stable, supporting an open scattered dune scrub, fernland, and vineland of bracken, small-leaved pōhuehue, toetoe, harakeke and cabbage trees. Locally, semi-stable dunes also include mānuka, kānuka, tutu and coastal tree daisy.

Coprosma acerosa. John Sawyer.

Characteristic native fauna:
Pre-human era: Dune habitats could have been used by giant, Mantell's and stout-legged moa, which browsed on dune shrubs and other vegetation (Atkinson & Millener 1991; Tennyson & Martinson 2006). Brown and little spotted kiwi, adzebill, various rails including weka and banded rail, and also shorebirds including oystercatchers, dotterels, gulls and terns, New Zealand quail, and some passerines such as pipit and New Zealand raven were probably also present (Atkinson & Millener 1991; Worthy & Holdaway 2002). Seabirds would have included little penguin and some of the smaller species of burrowing petrels and shearwaters (Atkinson & Millener 1991). Reptiles would have included tuatara, geckos and shore skinks.

New Zealand dotterel nest on dunes at Tawharanui Regional Park. **Alison Stanes.**

Present: Spinifex–pīngao grassland/sedgeland provides breeding habitats for shorebirds such as variable oystercatcher, New Zealand dotterel, gulls and endangered fairy tern. In the Auckland region, dunelands are the main stronghold for the New Zealand pipit, which has retreated from inland open country where aerial topdressing has altered, and improved, the rough pasture it prefers. Introduced birds include pheasant, brown and California quail, blackbird, song thrush, various finches, starling and myna. Shore skinks are scarce except where predatory mammals, such as rats, are controlled.

Key processes and Interactions: This ecosystem occurs on prograding coastlines where sand-binding plants such as pīngao and spinifex accumulate sand and form the dune profile (Esler 1970). Dune plants are tolerant of drought, salt spray, wind and sand accumulation and by trapping sand, protect the hinterland from storm surges. This ecosystem type is successional and with time more species invade, such as tauhinu, sand daphne and sand coprosma, and later trees (kānuka, and, locally, pohutukawa in northern New Zealand).

Threats: Active dunes have been greatly modified by human occupation, largely as a result of burning of vegetation and uncontrolled grazing, which caused large-scale and widespread mobilisation of both previously active and stable dunelands. To combat this, government-funded dune-stabilisation programmes were implemented using introduced species, several of which are significant invasive weeds (e.g. marram, lupin, sand wattle). Exotic forest now occupies a large proportion of former active dunelands, fragmenting remaining natural dunelands into small areas. Further, active dunelands have been invaded by a diverse range of weeds, which have displaced many native species. Many dunelands have been built on, especially on the eastern coastline of the northern North Island. Locally, off-road vehicles, wild horses and rabbits also cause significant damage.

Top image: Foredunes south of Karekare beach. **Jason Hosking.**
Bottom image: Union Bay, Karekare. **Jason Hosking.**

DN5 Oioi, knobby clubrush sedgeland

Regional IUCN threat status: Critically Endangered

Oioi, knobby clubrush sedgeland south of Karekare beach. **Jason Hosking.**

This ecosystem occupies dune plains or coastal plains (Esler 1969 & 1970), which are areas of flat land between dune ridges. Very similar vegetation locally occurs on wind-swept coastal hillslopes with raw, sandy soils, such as Āwhitu Peninsula. It is predominantly present in larger dunelands in association with mobile dunes and rapidly accreting coastlines. Dune plains are formed behind mobile dunes, that erode sand down to the water table or an impenetrable layer (e.g. relict beach gravels or shells). Immediately behind a moving dune, the base height of the new dune plain surface is variable and is related to either the height of the water table (at the time of formation), or an impenetrable layer. Moving dunes often form ephemeral wetlands (e.g. dune slacks), which are colonised by a group of wetland plants (Esler 1969, 1970; Burgess 1984; Singers 1997), including sand sedge, which capture sand and create small sand ridges.

Over time, succession of larger plants occurs (e.g. oioi), which further captures sand, raising the soil surface height. As a result, dune plains have a mosaic of areas, including periodically submerged wetland communities separated by small sand ridges and drier communities.

Flooding may occur at all times of the year following heavy rainfall (Singers 1997).

This ecosystem type includes the nationally rare ecosystems 'Dune deflation hollows', 'Damp sand plains' and 'Dune slacks' (Williams *et al.* 2007).

Distribution: North Island, largely in Northland (e.g. Aupōuri, Poutū, South Kaipara) and Foxton Ecological District (South Taranaki to Paekakariki); South Island (e.g. Farewell Spit, Canterbury, Otago, Southland) and Stewart Island. Historically, this ecosystem may have been present elsewhere (e.g. Matakana Island, Bay of Plenty) but no longer exists there. Good examples of this ecosystem type in the Auckland region are found at Whatipū and Papakanui Spit.

Characteristic native flora: Dune plains are initially colonised by sedgeland and herbfield of several local variants, with both dry and ephemerally wet communities. Dominant species include sand sedge, species of gunnera, clubrush, willowherb, geranium, pennywort, half star, *Ranunculus, Leptinella* and *Lobelia*, and locally, *Lilaeopsis novae-zelandiae*, *Myriophyllum votschii*, arrow grass, *Limosella lineata* and other turf-forming species. These are then succeeded by taller plants, especially oioi, knobby clubrush, toetoe and locally, coastal cutty grass. Locally, older successions include harakeke and mānuka.

Dry deflation hollows or sandy mounds are colonised by drought-tolerant species, including knobby clubrush, square sedge, silver tussock, jersey cudweed, scabweed and, locally, woollyheads.

Characteristic native fauna:
Pre-human era: Oioi–knobby clubrush sedgeland, especially in more open dune plain habitats, could have been used by giant, Mantell's and stout-legged moa which browsed on dune shrubs and other vegetation (Atkinson & Millener 1991; Tennyson & Martinson 2006). Brown and little spotted kiwi, adzebill, various rails including weka, banded rail, waterhen and crakes, various species of ducks, and also shore birds including oystercatchers, dotterels, gulls and terns, New Zealand quail and some passerines, such as pipit and New Zealand raven, could have also been present (Atkinson & Millener 1991). Reptiles could have included tuatara, geckos and shore skinks.

Present: These dune habitats provide seasonal habitats for waterfowl, crakes, pūkeko and bittern; breeding habitats for harrier and shorebirds such as variable oystercatcher, New Zealand and banded dotterels; and feeding and breeding habitat for pipit. Introduced birds include pheasant, brown and California quail, blackbird, song thrush, various finches, starling and myna.

Key processes and interactions: Formed by mobile dunes, dune plains often include a mosaic of both dry deflation hollows and seasonally wet areas, including sandy deflation hollows, sand plains, dune slacks and low mounds. Without disturbance (e.g. fire or smothering by another mobile dune), vegetation succession occurs, developing to flaxland–wetland scrub, cabbage tree carr and, eventually, swamp forest of pukatea and kahikatea.

Threats: Dune plains have been greatly reduced in extent, primarily as a result of development for exotic forestry or agriculture. Stabilisation of mobile dunes has resulted in the loss of early successional communities, and many remaining examples are fragmented and small. Weeds are a major threat, and dune plains are invaded by a wide range of species capable of transforming them to non-native-dominant communities. Of particular significance are pampas and leguminous herbs, which increase soil-nutrient levels and facilitate invasion by grasses (e.g. tall fescue, Yorkshire fog). Dune plains are also widely used and damaged by off-road vehicles.

Pipit. **Jason Hosking.**

Lilaeopsis novae-zelandiae. **Rebecca Stanley.**

Whatipū dune plains. **Alastair Jamieson.**

Geothermal ecosystems

Geothermal ecosystems occur where heat generated from the earth's interior rises to the surface, and is transferred directly through the ground or via water and steam. In New Zealand, geothermal activity is concentrated in the central North Island. Other smaller geothermal areas exist elsewhere, and in the Auckland region include small examples at Great Barrier Island, Parakai and Waiwera. Geothermal ecosystems are considered to be of limited extent and naturally rare (MfE and DOC 2007).

There are two geothermal ecosystem types recognised nationally. Historically, in Auckland, there were small areas of geothermally-heated water and steam (GT2); however the natural ecosystems associated with surface springs at Parakai and Waiwera have now been lost as a result of development. Auckland's remaining natural geothermal ecosystem occurs at Kaitoke hot springs, situated along the western margin of Kaitoke Swamp on Great Barrier Island. The hottest spring reaches 84°C, and the waters contain high levels of sodium chloride (salt), potassium and calcium, and it gives off small amounts of gas including nitrogen, methane and carbon dioxide (Armitage 2001).
The source of the springs is thought to be a reservoir under the island where the water may reach up to 250°C. It slowly cools as it percolates to the surface, leaching minerals from the surrounding volcanic rock (Armitage 2001).

Geothermally-heated water and steam ecosystems provide microhabitats that support biota adapted to the temperature, chemistry and hydrology of the site (Given 1980, Burns 1997, Merrett & Clarkson 1999, Duggan *et al.*, 2007, Boothroyd 2009).

Image left: Bath houses at Waiwera hot springs, early 1900s.
William A. Price Collection, Alexander Turnbull Library.

Several native plant species (e.g. marsh fern and *Cyclosorus interruptus*) are able to grow outside their normal latitudinal and/or altitudinal range because the sites provide aspects of the species' usual habitat, such as protection from frosts for frost-intolerant species (Given 1995, de Lange 2011). Other species, for example, whisk fern are strongly associated with geothermal areas (de Lange 2011).

Notable fauna from New Zealand geothermal streamside ecosystems include the ephydrid fly, *Ephydrella thermarum*, and a mosquito species (*Culex rotoruae*). Both were recorded during research in the geothermal waters of the Taupo Volcanic Zone (Duggan *et al.*, 2007, Boothroyd 2009).
Weed invasion and habitat modification as a result of development, are significant threats to geothermal ecosystems in New Zealand.

GT2

Geothermally-heated water and steam

Regional IUCN threat status: Data Deficient

In volcanic fields and near tectonically active fault-lines where magma (molten rock) occurs close to the earth's surface, ground-water percolates towards the magma through rock fractures and deep faults. Deep below the surface, this water is heated to high temperatures (>300°C), dissolving minerals such as silica and sulphur from bed-rock. This hot, mineral-rich water then rises to the surface, where it may form natural features such as hot and boiling springs and streams, geysers, mud-pools, silica sinter deposits/terraces, fumaroles, and hot and steaming ground (Cody 2007).

Heated waters span a wide range of pH conditions, from neutral to weakly alkaline (pH >6.6) to highly acidic (pH <3.0), and temperatures (<25°C to >100°C). Heated waters contain a wide range of minerals and are often described as being chloride, bicarbonate, chloride-sulphate, acid sulphate or sulphate fluids (Cody 2007). The temperature range and chemical composition of the heated water influence species composition.

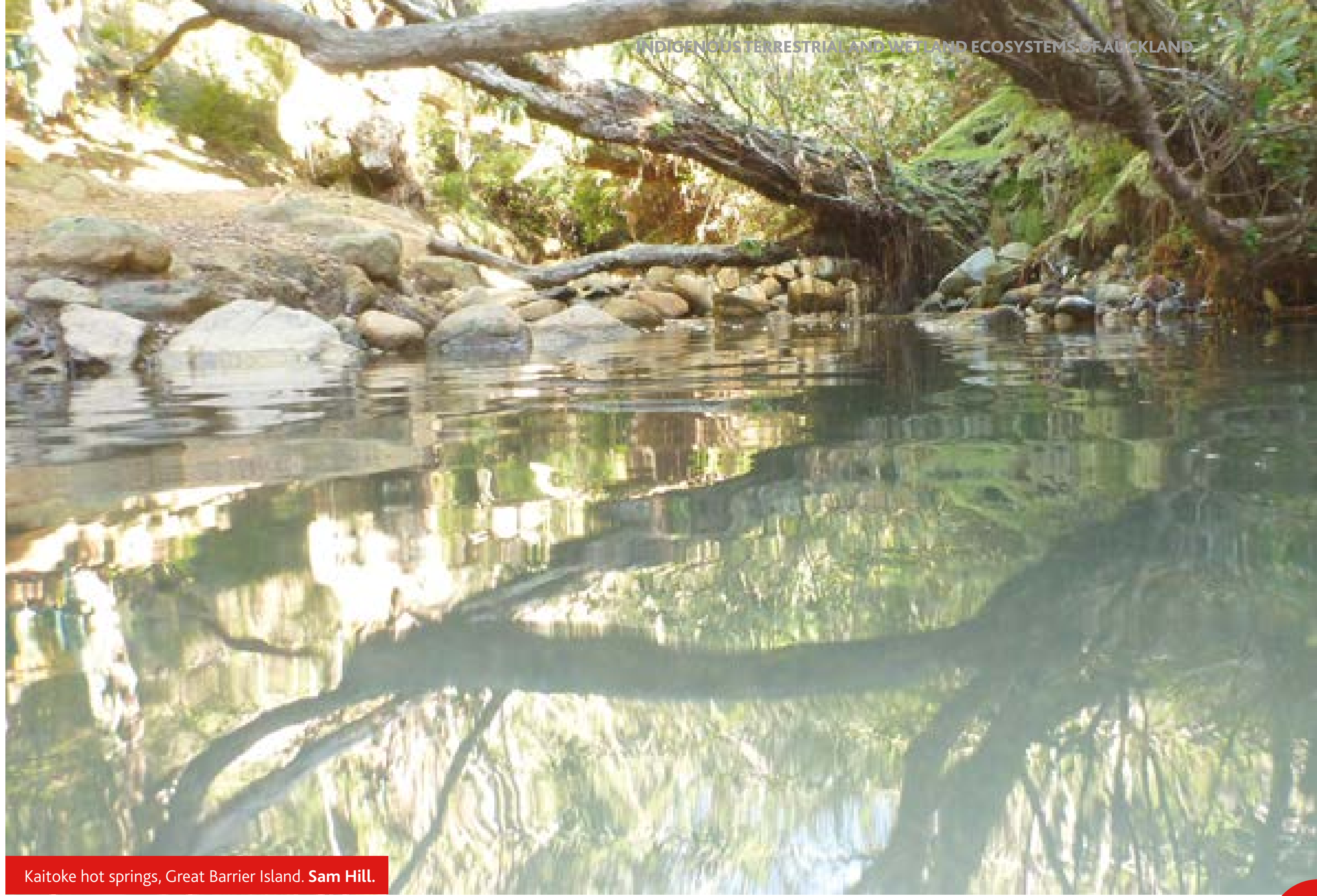
Distribution: This hot water ecosystem type predominantly occurs and is most extensive in the Taupo Volcanic Zone (Boothroyd 2009), though there are small examples in Northland (e.g. Ngāwhā) and the Auckland volcanic centres. Hot springs are also associated with tectonically active faults, generally close to the axial ranges, in the central North Island and South Island from South Marlborough to South Canterbury (Stark *et al.* 1976). The only remaining, unmodified example of this ecosystem type in the Auckland region is found at the Kaitoke Hot Springs, Great Barrier Island.

Characteristic native biota: Geothermally-heated water contains a wide diversity of organism types, including some thought to be among the oldest life known on the planet. Much of the biodiversity is dominated by micro-organisms that occur in geothermal systems worldwide. Biodiversity of heated water is strongly separated by temperature and chemical gradients and includes prokaryote and eukaryote micro-organisms, as well as algae, fungi, bryophytes and invertebrates. Micro-organisms include species of fungi, bacteria, archaebacteria, cyanobacteria, diatoms, tasmanitids and amoeba (Stark *et al*. 1976; Cody 2007; Boothroyd 2009). Over 200 different species of algae, from diatoms to cyanobacteria, are known to occur in thermal waters (Cassie-Cooper 1996). Commonly occurring invertebrates include mayflies, crane flies, midges and molluscs.

Prehuman era: There is little information on the pre-human fauna of thermal ecosystems, but some of them were possibly visited by moa, which would have browsed vegetation in downstream wetlands and around the margins (Tennyson & Martinson 2006). A range of other birds probably occurred in the downstream wetlands nearby including adzebill, flightless goose, swan, Australasian and little bitterns, various ducks, rails, snipe and passerines, especially fernbird (Atkinson & Millener 1991; Worthy & Holdaway 2002). Several gecko species, including green and forest geckos, were probably also present, especially in low scrub around the margins.

Present: Today fernbirds commonly occur in scrublands around the margins of these ecosystems, and green and forest geckos occur where mānuka is present. Downstream wetlands and scrublands provide habitat for Australasian bittern, banded rail, spotless crake, pūkeko, some waterfowl, harrier, kererū, shining cuckoo, kingfisher, fantail, grey warbler, tūī and silvereye. Introduced birds include mallard, pheasant, California and brown quail, dunnock, blackbird and chaffinch.

Steam-influenced zones adjacent to geothermal waters that are near neutral pH may support a small number of ferns of tropical origin (e.g. *Christella*). Where cool or tepid geothermal water collects, distinctive geothermal wetlands may develop that support a small number of vascular plants more commonly associated with coastal



Kaitoke hot springs, Great Barrier Island. **Sam Hill.**

wetlands, such as coastal cutty grass, oioi and arrow grass.

Key processes and interactions: Geothermally-heated water and steam ecosystems are extreme environments for life, having high temperatures, dissolved minerals and often low acidity. The full composition of this ecosystem type is still being researched. Biodiversity is known to be different in heated waters with different chemical compositions, e.g. hot alkaline waters and hot acidic waters (Boothroyd *et al.* 2006). In hot streams, communities are separated into zones defined by temperature gradients. At the highest temperatures (74–115°C), thermophilic fungi, cyanobacteria and archaebacteria occur, including species that may use sulphur compounds (instead of oxygen) for respiration. In silica-rich waters, these organisms assist in building microstromatolites and sinter formation (Jones *et al.* 1997, 1999; Handley *et al.* 2005). Between 55° and 73°C, a diverse array of photosynthetic algae and cyanobacteria occur and are often abundant. Invertebrates occur below 55°C, and invertebrate communities are generally simple with low species diversity, though some individual species can be abundant. Very few invertebrates are endemic to thermal waters, though a mosquito-like fly (*Ephydrella thermarum*) only occurs in geothermally-heated water (Boothroyd 2009).

Threats: Aquatic biodiversity of hot and boiling waters is completely dependent on the natural features associated with high-temperature geothermal fields. This biodiversity is very susceptible to damage from a wide range of land-modification activities, particularly farming, forestry, mining, flooding for dams and energy extraction. Several geothermal fields in the Taupo Volcanic Zone are exploited for heating, industrial and electricity purposes and this has directly resulted in many natural features and their associated biodiversity being damaged or destroyed. For example, Wairakei Power Station resulted in the destruction of over 30 geysers in the former geyser valley at Wairakei, as well as several other heated streams (Cody 2007). Modern development however, now generally involves reinjection to maintain aquifer pressure, and this is helping to conserve surface features.

While terrestrial geothermally-heated soils and ecosystems are threatened by invasive species such as weeds, far fewer invasive species occur in aquatic geothermal systems. Some species of tropical fish (sail-fin mollies, guppy and swordtail) are known to occur at a few locations in suitably warm waters (McDowall 2000), however these have narrow tolerances of temperature and their impact on the invertebrate populations is unknown.

Cave ecosystems

Terrestrial subterranean or cave ecosystems are exposed to air but occur under the ground. There is one cave ecosystem type identified nationally: the subterranean rockland/stonefield (CV1). Caves in New Zealand are generally found in limestone karst or basalt volcanic environments. Basalt lava fields such as the Auckland Volcanic Field contain subterranean networks of cooling cracks, voids and occasional lava tubes (caves), and these are recognised as a naturally uncommon ecosystem type in New Zealand (Williams *et al.* 2007).

The Auckland Volcanic Field has more than 50 known caves of 20m or longer, with many others thought to have been destroyed or yet to be unearthed (Lomas 2006). Wiri lava cave is regarded as the best example of a lava cave in New Zealand (Crossley 2014). It is Auckland's best-preserved and longest known cave, measuring 290m in length and up to 6m in diameter. Other relatively substantial caves occur within the lava flows of One Tree Hill, Mt Albert and Three Kings volcanoes, and there are lava caves accessible to the public on Rangitoto Island (Crossley 2014).

Little is known about the biota of Auckland's lava caves, but as the volcanic field is relatively young, few species are likely to have evolved to inhabit the voids (Lynn *et al.* 2016).

Threats to caves include earthworks, urban development, quarrying, alteration to natural underground water flows, and the introduction of stormwater, sediment and pollutants (Lomas 2006).

Image left: Wiri lava cave near Manukau is Auckland's longest known lava cave. **Alastair Jamieson.**

CV1 Subterranean rockland/ stonefield

Regional IUCN threat status: Data Deficient

Most caves form over hundreds of thousands to millions of years in calcareous rocks, such as limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), which react with weakly acidic ground water. Over a long period of time, groundwater enters fractures in the rock and moves downwards through it, dissolving, slowly eroding and altering it, and usually exits at the edge of the calcareous rock formation as a spring. Lava caves develop as tubes within basalt flows during eruptions while the lava is still fluid (Hamilton-Smith & Finlayson 2003). Cave ecosystems have a saturated humidity and a constant temperature that is usually close to the mean annual temperature of their geographic location (Hunt & Millar 2001).

Distribution: Found in karst and pseudo-karst areas, associated with carbonate (limestone, marble, dolomite) parent materials, primarily in humid and sub-humid climatic zones, such as parts of Northland and the King Country to inland Taranaki, north-west Nelson and the West Coast. Cave systems are most extensive in areas of high rainfall.

Caves also occur in association with basaltic volcanoes in the Auckland region (Williams *et al.* 2007).

Characteristic native flora: Plant roots are a beneficial component of cave ecosystems and provide an important source of food or energy input into the ecosystem (Lynn *et al.* 2016). Pōhutukawa and puka roots penetrate lava caves on Rangitoto Island and gorse roots penetrate the Wiri cave. Maidenhair and kidney ferns are often found at cave entrances (Peter Crossley – pers comm.). Tree roots are a source of refuge for cave dwelling insects including cave wētā (Crossley 2014).

Characteristic native fauna: Cave ecosystems are dominated by a range of detritivorous and predatory organisms that include microbes, and terrestrial and aquatic invertebrate species, both epigean and specialist troglobites. Plant and animal material that enters or dies in the cave is consumed by these organisms. The ecosystem includes species of molluscs, flies, glow worms, spiders, ground beetles, pseudo-scorpions and amphipods (May 1963; Townsend 1963; Climo 1974; Johns 1991; Hunt & Millar 2001). Very little is known about the fauna of New Zealand caves (Hunt & Millar 2001); however it appears that it can be archipelago-like, with local endemism, between geographically-isolated karst blocks.

Pre-human era: Subfossil deposits show that caves and sinkholes in karst country were traps for most indigenous vertebrate species (Atkinson & Millener 1991; Worthy & Holdaway 2002), but few species actually used caves. Cave-using species included little bush moa, which nested under overhangs, little penguin, reef heron, laughing owl, owlet-nightjar, roosting saddleback and bats. In the Auckland region, lava caves could have been used by some of the above species.

Present: Today, lava caves on Rangitoto are used by nesting swallows and possibly by roosting saddlebacks. Invertebrate cave fauna includes glow worms and cave wētā.

Key processes and interactions: Cave ecosystem energy inputs are limited to detritus and material that falls or is washed into the cave from outside, or organisms that enter and die in the cave. Material includes silts, plant debris, dead animals and their wastes (Hunt & Millar 2001). Species may occupy both terrestrial and aquatic environments in the cave, because the terrestrial cave environment has a saturated humidity.

Threats: New Zealand cave ecosystems have fewer threats than terrestrial ecosystems. The greatest threat to the natural ecology of caves is associated with changes in use of the land above the cave or the land that supplies water to the cave. Land development and deforestation can increase erosion rates, resulting in an increased volume of water, sediment and nutrients entering the cave system.

These factors can all potentially change the hydrological functioning of the ecosystem as well as the composition of the invertebrate communities. Rats are also known to enter and forage in cave ecosystems, preying on the invertebrates present, though the level of impact they have on these organisms is unknown (Hunt & Millar 2001).

Below: Lava cave on Rangitoto Island. **Sam & Bevan Hill.**

Anthropogenic ecosystems

Since arriving in New Zealand, humans have influenced the composition and structure of its ecosystems. The use of fire by Maori resulted in the loss of approximately one third of previously forested ecosystems (McGlone 1983), leading to a range of vegetation successions, which are covered in the ecosystem classification system (Singers & Rogers 2014). Most of these vegetation successions are common today, especially in marginal pastoral lands. Species extinctions would also have modified ecosystems, though compared with loss from fire, change was probably much more subtle. Recent dietary studies of moa in Central Otago suggest that their browsing maintained a much more open forest structure, where trees co-existed with areas of herbaceous turf (Wood *et al*. 2008). European colonisation however has had a much greater impact, especially the effects of introducing thousands of species of alien plants and animals.

Contemporary ecosystem composition is now strongly influenced by a combination of factors, in which alien species frequently play a significant role. Succession through gorse is one example, which results in different vegetation successional pathways and therefore different forest composition, compared with succession through mānuka or kānuka (Wilson 1994). The influence on vegetation succession by browsing mammals is also a major ecosystem determinant. Where ungulate and possum populations are unmanaged, browsing can result in diverse forests being replaced by a few unpalatable species.

A similar process occurs on marginal farmland where vegetation succession of native and alien mosaics is leading to novel ecosystem compositions. Tōtara is profusely regenerating as a pioneer in marginal pasture in northern New Zealand due to a combination of factors, including its unpalatability to cattle, and ease of establishment in short pasture and on ground disturbed by stock (Bergin & Kimberley 2014). This process has resulted today in over 60,000 hectares in Northland now dominated almost exclusively by a monoculture of tōtara — these same sites would have previously supported a much more diverse forest.

The long term viability and successional trajectory for these ecosystems is unknown.

Image left: Gorse with regenerating native species at Takatu Point, Tawharanui Regional Park. **Tim Lovegrove.**

AVS1 Anthropogenic tōtara forest

Anthropogenically induced tōtara forest occurs in areas of moderately steep pastoral hill country of low to moderately-low fertility in sub-humid and semi-arid regions, which before human deforestation would have supported much richer forest compositions. Localised regeneration is also occurring on alluvial soils, though in these locations tōtara was a dominant component of the original forest (Duguid 1990; Beadle *et al.* 2000).

Tōtara has many characteristics of a long-lived pioneer species with the ability to regenerate rapidly after a catastrophic disturbance with seed which is widely dispersed by small birds. Tōtara regenerates well in high light environments. It is tolerant of edaphically dry situations and is resistant to herbivory. Consequently, tōtara forest was naturally most abundant along river margins and after volcanic eruptions and fires. Anthropogenic tōtara forest, however, occurs in pastoral landscapes.

Distribution: Anthropogenically induced tōtara forest is most abundant north of Auckland although is also locally present in the Waikato, King Country, Hawkes Bay, Wairarapa, Horowhenua and Nelson districts (Elder 1949; Duguid 1990; Beadle *et al.* 2000; Bergin 2003). In Auckland, it is most abundant in the Rodney Ecological District, although it also occurs in the Manukau Ecological District.

Characteristic native flora: In Northland, tōtara is the dominant colonising species, typically in association with kānuka and, locally mānuka. In more humid sites kahikatea may also be present. Gorse is also often present and can be co-dominant although along with mānuka and kānuka, is suppressed by tōtara regeneration as stands mature. The forest understorey is sparse with little undergrowth as a result of grazing (Bergin 2003).

Characteristic native fauna: Anthropogenic tōtara forest supports a range of forest birds such as kereru, morepork, kingfisher, fantail, grey warbler, silvereye and tūī, and also lizards including geckos. In Northland, tōtara forest is often habitat for brown kiwi.

Key processes and interactions: This successional ecosystem occurs in mild to warm areas of the North Island. Tōtara regeneration in low-producing pastures has been most intensely studied in Northland. It regenerates most prolifically on slopes greater than 20° with a diverse, but poor quality exotic pasture with less than 50 per cent cover with soils of low to moderately low fertility. Cattle grazing probably also encourages establishment by damaging pastures and baring the soil for seed establishment through pugging and other damage. In these areas tōtara grows relatively quickly because of its drought tolerance, lack of palatability to cattle, and reduced competition with pasture species grazed by stock. Regeneration is almost non-existent in more fertile flat to gradually-sloping land and is less vigorous where sheep grazing is the dominant land use (Bergin 2003; Bergin & Kimberley 2014).

The establishment of many anthropogenically induced tōtara forests coincided with periods of initial forest clearance and some are now over 100 years old, though stands of all ages are present in Northland where it is most abundant (Bergin 2003; Elder 1949).

Threats: Nationally, this ecosystem is increasing in marginally economic hill country of low to moderately low fertility. Regeneration is more likely to have occurred where tōtara seed sources remained following pasture conversion, rather than because of any underlying environmental factor. While some areas of tōtara forest have been set aside as reserves, areas have also been lost primarily through land conversion to exotic forestry. As many stands are still relatively young, limited extraction for timber has occurred, however tōtara forestry is being promoted as a specialist timber resource and an industry is developing (Bergin 2003).

Sustainable timber extraction is unlikely to be a direct threat, especially if more land is allowed to regenerate as a preferred land use. It is possible that as these stands mature and become economic for harvesting, whole areas could be felled and they may not be replaced.

Image right: Anthropogenic tōtara forest in the Whangaripo valley. **Jason Hosking.**

Appendix

A quick guide to Auckland terrestrial & wetland ecosystems using a hierarchy of environmental gradients and factors as an abiotic framework against which diagnostic species are arranged.

Table 1: Forest ecosystems

Ecosystem drivers			Ecosystem unit/ variant		Diagnostic species	Diagnostic features
Temperature and humidity	**Landform**	**Soils and fertility**	**Code**	**Ecosystem name**		
Warm temperate and sub-humid	Hill-slopes and hill-crests exposed to frequent coastal winds and salt spray.	Moderate to low fertility, including allophanic, brown, granular, recent and ultic soils.	WF4	Pōhutukawa, pūriri, broadleaved forest **[Coastal broadleaved forest]**	Pōhutukawa, pūriri, kohekohe and locally taraire, karaka, tawa, tītoki, mangeao, rewarewa, puka, tawāpou, ngaio and nīkau.	**Coastal broadleaved forest.** Mostly up to 600-800m from shore, but further inland in exposed locations. On sheltered coastlines, pūriri often common and pōhutukawa may be absent. Does not include coastal forest on stabilised dunes (WF5). Away from the coast this species mix could be WF7, WF9, or gully vegetation of kauri forest types (WF10, WF11 & WF12). Classify as treeland (TL) if tree and shrub cover is <80%.
	Stable dunes	Free-draining sandy brown soils and acidic orthic recent soils. Fertility is generally low.	WF5	Tōtara, kānuka, broadleaved forest **[Dune forest]**	Kānuka and pōhutukawa. Historically also included tōtara, tītoki, māhoe and rewarewa.	**Dune forest on stabilised dunes** ranging from recent Holocene coastal sands to Pleistocene sands with higher (10-20%) clay content. South Head peninsula and on western side of Awhitu Peninsula in Auckland.
	Alluvial terraces	Recent, free-draining (often stony) soils of moderate to high natural fertility.	WF7.1	Pūriri, tōtara forest	Pūriri with occasional tōtara, mataī, kahikatea and tītoki, locally with kōwhai and taraire.	Very little left in Auckland. Originally abundant on the Auckland isthmus, in the large river valleys of the north including Riverhead, Coatesville, Waikoukou Valley and Kaukapakapa; and in the south it was widespread on the Mānukau and Franklin lowlands and on SE Awhitu. Includes **volcanic rock forest** remnants (WL7.2). Easily confused with **WF9, WF10, WF11 & WF12**. Differentiate from these by topography and soil type. **WF4** if exposed to coastal influences.
	Flat to rolling land	Volcanic loams derived from basalt e.g. orthic granular soils, oxidic granular soils, orthic melanic soils, oxidic brown soils.	WF7.2	**Pūriri,** taraire forest	Pūriri with locally abundant taraire and kohekohe and occasional pukatea, rewarewa, karaka, tawa, tītoki and northern rātā. Historically also included tōtara and mataī.	
	Narrow river valleys and wide flood plains and undulating to rolling terraces	Imperfectly drained recent fluvial soils and orthic allophanic soils and locally perch-gley melanic soils and mottled orthic recent soils.	WF7.3	Kahikatea, **pūriri** forest	Pūriri, kohekohe and with **occasional emergent kahikatea.**	
	Recent alluvial terraces and older dune plain basins	Poor-draining gley and organic soils and small areas of sandy perch-gley ultic soils and humus-pan podzols.	WF8	**Kahikatea, pukatea** forest	Kahikatea and or pukatea and locally rimu, swamp maire and tawa.	**Swamp forest with seasonally high water tables. Kiekie, supplejack** and **mapere** common in understorey. Could be confused with **MF4:** Kahikatea forest, which is typically found in colder, more frost-prone areas and has different understorey composition. Also could be confused with gully component of kauri forest types (WF10-12). Check topography and soils.
	Rolling hill-slopes and older alluvial surfaces (below 450m a.s.l.)	Brown, granular and recent soils and andesitic and basaltic derived clay loams of moderate fertility.	WF9	**Taraire,** tawa, podocarp forest	Taraire, kohekohe, tawa and locally tōwai with emergent rimu, northern rātā and kahikatea in gullies.	**Taraire dominated.** No kauri. Older soils than **WF7**. **WF4** if exposed to coastal influences. Could be gully component of kauri forest types (**WF10-12**). Check soil type to differentiate.

INDIGENOUS TERRESTRIAL AND WETLAND ECOSYSTEMS OF AUCKLAND

Table 1: Forest ecosystems continued

Ecosystem drivers			Ecosystem unit/ variant		Diagnostic species	Diagnostic features
Temperature and humidity	**Landform**	**Soils and fertility**	**Code**	**Ecosystem name**		
	Hill-slopes and hill-crests	Ultic or oxidic soils developing towards podzols that are often seasonally waterlogged and of low fertility.	WF10.1	**Mature** kauri forest	Mature abundant to common kauri. Also small statured miro, rimu, toatoa, thin-barked tōtara, tōtara, tānekaha, monoao, rātā, tawa, taraire, hīnau, rewarewa, kohekohe and tōwai.	**Dense stand of large kauri**, often of similar size/age. Sub-canopy characterised by kiekie, *Dracophyllum* spp., *Gahnia* spp. and kauri grass.
			WF10.2	Kauri ricker forest	Pole and ricker kauri, tānekaha often also tōtara, rewarewa and tōwai.	**Extremely dense stands of young kauri** with other tree species occasionally interspersed.
	Hill-slopes and hill-crests	Ultic, oxidic soils developing towards podzols or recent soils of low fertility.	WF11	Kauri, podocarp, broadleaved forest	Kauri, rimu, tōtara, thin-barked tōtara, miro, tānekaha, kahikatea and taraire, kohekohe and pūriri and/or tawa, tōwai.	Widespread **diverse forest with kauri interspersed**, although most dominant on upper slopes/ridges. Broadleaved species and kahikatea common in gullies. Often only gully component of this ecosystem type remains and kauri is absent.
	Hill-slopes and hill-crests on sandstone, mudstone and greywacke	Ultic and brown soils of low fertility, derived from weathered parent materials such as greywacke, argillite, dacite and rhyolite.	WF12	Kauri, podocarp, broadleaved, **beech** forest	Kauri, **hard beech** and tānekaha. Also thin-barked tōtara, tōtara, rimu, miro, tawa, hīnau, northern rātā, rewarewa, tōwai and, locally, kohekohe, narrow-leaved maire and tāwari.	**Hard beech** interspersed with kauri, podocarp and broadleaved species. Classify as WF11 if beech occurs only occasionally (as is often the case in Rodney).
	Shallow to steep hill-slopes and gullies 150–550 m a.s.l. especially in the Hunua and Waitākere Ranges	Moderately fertile soil types, including allophanic, brown, and recent soils.	WF13	**Tawa, kohekohe,** rewarewa, hīnau podocarp forest	Tawa and kohekohe. Also rimu, northern rātā, miro, hīnau, rewarewa, locally mangeao, pukatea and kahikatea.	**Tawa and kohekohe** most dominant canopy species. Kauri absent. Largely restricted to Hunua Ranges and Waitākere Ranges.
Mild	**Frost prone recent alluvial terraces**	Moderate to high-fertility poorly drained gleyed and organic gleyed soils.	MF4	**Kahikatea** forest	Kahikatea, **ribbonwood, *Hoheria* spp, kōwhai**, tītoki, pōkākā, māhoe, kaikōmako and divaricating shrubs including tūrepo, round-leaved coprosma and poataniwha.	**Kahikatea swamp forest dominant**. Typically found in frost-prone areas, e.g. Kaipara Flats, Coatesville, Riverhead and Clevedon. Could be confused with **WF8** but different understorey composition. Also could be confused with gully component of kauri forest types (**WF11-12**). Check topography and soils.
Mild temperate and humid	Hill-slopes, hill-crests, and plateaux	Low-fertility leached brown and granular soils developing towards podzols.	MF24	Rimu, tōwai forest	Tōwai and emergent rimu, northern rātā and miro. Locally also includes tawa.	**High altitude (>450m)** forest in **Hunua Ranges.**
	Hill-slopes and hill-crests.	Strongly leached low-fertility brown soils developing towards podzols.	MF25	Kauri, tōwai, rātā, montane podocarp forest	Tāwari, tāwheowheo and southern rātā with stunted conifers including kauri, toatoa and Hall's tōtara. Silver pine, monoao and yellow-silver pine on GBI.	**High altitude forest on Little Barrier (LBI) and Great Barrier Islands (GBI)** (>600m on LBI and Mt Hobson on GBI).

Table 2: Cliff ecosystems

Ecosystem drivers			Ecosystem unit/ variant		Diagnostic species	Diagnostic features
Physical disturbance	**Temperature and humidity**	**Landform**	**Code**	**Ecosystem name**		
Erosion associated with gravity and wind ablation	Warm temperate and sub-humid.	**Coastal** cliffs, bluffs, rock-stacks, and their talus in association with atmospheric salinity (e.g. spume and salt-spray).	CL1	Pōhutukawa treeland/ flaxland/rockland	Pōhutukawa, houpara, taupata, karo, wharangi, kawakawa and tūrepo. New Zealand broom, species of hebe, harakeke, rengarenga lily, coastal astelia, knobby clubrush.	Coastal cliffs, erosion-prone hill-slopes and colluvial slopes with pōhutukawa treeland, shrubland, flaxland and/or rockland. Grades into WF4 (coastal forest) on and above coastal escarpments where easier terrain permits forest establishment. Classify as treeland (TL) if tree and shrub cover is <80%.
	Warm to mild temperate and semi-arid to sub-humid.	**Inland** cliffs, bluffs, tors, and their talus.	CL6	Hebe, wharariki flaxland/rockland	Wharariki, broad-leaved poa, hebe species, snowberry, New Zealand daphne, tree daisy, kōwhai and New Zealand broom, mingimingi, *Dracophyllum*, broadleaf, mānuka, tutu and, locally, rātā lianes, ngaio, kānuka, perching lily, tūrutu and locally tank lily and harakeke.	Inland cliffs, rock outcrops and bluffs. Vegetation includes lichens, bryophytes, short-statured herbs, grasses, wharariki, shrubs and low forest species. Most common in Auckland on bluffs in Waitākere and Hunua Ranges.

Table 3: Regenerating ecosystems

Ecosystem drivers			Ecosystem unit/ variant		Diagnostic species	Diagnostic features
Combustion and/or volcanicactivity [Vegetation succession]	Temperature and humidity	Landform	Code	Ecosystem name		
Large-scale disturbance associated with fire or erosion or volcanic activity	Warm and sub-humid	Hill-slopes, ridges, terraces.	VS1	**Pōhutukawa scrub/ forest**	Pōhutukawa, northern rātā, puka, kānuka, karamū, akepiro, koromiko, Kirk's tree daisy, māpou, rewarewa and akeake are also locally present.	**Early successional pōhutukawa-dominated forest and scrub on Auckland lava flows**. Largest sites in Auckland are Rangitoto Island and an area of rockfall (Pohutukawa Flat) on Hauturu / Little Barrier Island.
	Warm to cool temperate and semi-arid to sub-humid	Hill-slopes, ridges, terraces, and plains especially on free-draining soils.	VS2	**Kānuka scrub/forest**	Kānuka, mingimingi, prickly mingimingi, *Coprosma rhamnoides*, tauhinu, kōhūhū, māhoe, māmāngi, five-finger, lancewood, kōwhai, karamū, putaputawētā.	Kānuka-dominated forest with insufficient emergent secondary species to determine trajectory to mature forest type. WF5 if on stabilised dunes.
	Warm to cool temperate and sub-humid.	Hill-slopes, ridges, and terraces on free-draining soils.	VS3	**Mānuka, kānuka scrub**	Mānuka and kānuka. Also present hangehange, māhoe, species of *Coprosma, Pittosporum* and *Pseudopanax*, locally kawakawa, māpou, rewarewa and tree ferns.	**Mixed mānuka-kānuka scrub** (can be mānuka dominated in exposed locations) with insufficient emergent secondary species to determine trajectory to mature forest type. Further down the soil fertility and drainage continuum with more fertile and better drained soils than WL1 (gumland). Presence of kānuka, tree ferns, and broadleaved species such as hangehange indicates VS3 rather than WL1. Differs from mānuka-dominated fen wetland (WL12), which typically has a higher water table, better soil fertility, and a different species assemblage.
	Warm to cool temperate and sub-humid to humid	Hill-slopes, ridges, and terraces on low-fertility soils.	VS5	**Broadleaved species scrub/forest**	Species of *Coprosma* (especially māmāngi karamū, shining karamū and kanono), *Pseudopanax, Pittosporum*, tree daisy, hebe, rangiora, tutu, putaputawētā, māhoe, māpou, wineberry, kōtukutuku, patē, tōwai and tree ferns.	Scrub/forest dominated by **early successional broadleaved species** often with abundant tree ferns. Insufficient emergent secondary species to determine trajectory to mature forest type. Includes young broadleaved dominated (e.g. māhoe) scrub/forest dominated on lava flows.

Table 4: Wetland ecosystems

Ecosystem drivers			Ecosystem unit/ variant		Diagnostic species	Diagnostic features
Hydrosystem	Fertitility or chemistry	Landform	Code	Ecosystem name		
Freshwater [including palustrine, riverine and lacustrine]	Oligotrophic-low nutrient status and high acidity [bogs]	Hill-slopes and depressions with **kauri podzols**	WL1.1	Gumland heath	Mānuka, gumland grass tree, tangle fern, species of *Machaerina, Schoenus, Gahnia, Tetraria* and *Lepidosperma* sedges, and locally tamingi.	Waikumete Cemetery is the only known true gumland heath site in Auckland (per Clarkson *et al.* 2011 definition).
		Ultic soils or abated soil (lacking A or B horizon) of low fertility and occasional fires	WL1.2	**Fire-induced** gumland heath	Mānuka, *Dracophyllum* spp., tangle fern, sword sedge, kauri sedge, kūmarahou, toru.	Gumland that doesn't meet the true gumland definition characterised by low scrub, sedgeland and fernland. Low-fertility and acidic soil, poor drainage, often seasonally dry. May succeed to kauri forest if left undisturbed. Differs from mānuka-kānuka scrub (VS3) which has more fertile and better-drained soils. Presence of kānuka, tree ferns, and broadleaved species such as hangehange indicates VS3 rather than WL1. Differs from mānuka dominated fen wetland (WL12), which typically has a higher water table, better soil fertility, and a different species assemblage.
		Depressions or the lagg of raised bogs with organic soils.	WL2	Mānuka, greater wirerush, restiad rushland	Mānuka, tamingi, greater wirerush, tangle fern, *Schoenus brevifolius, Machaerina tenax*, sphagnum and *Tetraria*.	Only known from dune lakes in the north-east of the region.

INDIGENOUS TERRESTRIAL AND WETLAND ECOSYSTEMS OF AUCKLAND

Table 4: Wetland ecosystems continued

Ecosystem drivers			Ecosystem unit/ variant		Diagnostic species	Diagnostic features
Hydrosystem	Fertility or chemistry	Landform	Code	Ecosystem name		
		Raised bogs on in-filled lagoons/ river oxbows with deep organic soils.	WL3	**Bamboo rush**, greater wirerush, restiad rushland	**Bamboo rush**, greater wirerush, mānuka, gumland grass tree, Sinclair's tamingi, *Lycopodiella lateralis, Machaerina teretifolia, Schoenus brevifolius,* tangle fern, sphagnum, *Utricularia and Drosera* spp.	'Collapsed' in the Auckland Region (equivalent to species extinction).
	Mesotrophic- moderate fertility and weak to neutral acidity [fens and marshes]	Freshwater margins of estuaries, tidal rivers, coastal lagoons, and some inland lakes.	WL10	Oioi restiad rushland/reedland	Abundant oioi, locally with large **Machaerina** and **Bolboschoenus spp., kuta, lake clubrush,** often with scattered **raupō** and **harakeke**.	On stream margins where freshwater meets saline at the coast, in estuaries and in coastal lagoons. Differentiated from SA1.3 (estuarine saltmarsh) and DN5.1 (dune plains), which are often dominated by oioi, by the influence of freshwater and the presence of the other wetland species listed.
		Depressions and lake and lagoon margins.	WL11	*Machaerina* sedgeland	Species of *Machaerina*, *Eleocharis*, lake clubrush and locally *Carex* spp.	A relatively common sedgeland-rushland wetland type.
		Depressions.	WL12	Mānuka, tangle fern, scrub, fernland	Mānuka, *Machaerina*, *Lepidosperma*, tangle fern, sphagnum, *Carex* spp., *Gahnia* and *Astelia* species.	**Mānuka-dominated wetland.** Fluctuating water table. Often occurs in small patches on edge of WL11 or WL2. Largest examples on GBI. Could be confused with WL1 (gumland) or VS3 (scrub) where mānuka is also dominant, but has different species mix, hydrology and soils.
		Coastal lake and lagoon margins.	WL15.1	**Herbfield [coastal lakeshore turf]**	Half star, bachelor's button and species of water milfoil, *Crassula, Isolepis, Leptinella, Lobelia* and buttercup. Also *Limosella lineata* and *Lilaeopsis novae-zelandiae.*	Narrow band of permanent herbfield on edge of fluctuating lakeshore margins, often between aquatic (hydrophytic) vegetation and taller lakeshore emergent vegetation. Occurs on shallow-gradient lake margins in freshwater and brackish conditions, towards the sea. Grades into salt marsh with increasing salinity. Could be confused with other herbfield ecosystems: SA5 (exposed coast), SA1.4 (estuarine) or DN5.2 (dune slack), though WL15.1 is dominated by hydrophytes tolerant of submergence.
		Inland lake and lagoon margins.	WL15.2	Herbfield [inland lakeshore turf]	*Glossostigma elatinoides*, species of water milfoil, *Lilaeopsis*, *Carex*, *Eleocharis*, *Lobelia*, *Centrolepis*, *Hydrocotyle*, *Plantago*, *Ranunculus*, *Crassula* and *Viola.*	Narrow band of permanent herbfield on edge of fluctuating lakeshore margins, often between aquatic (hydrophtic) vegetation and taller lakeshore emergent vegetation. Ecosystem occurs on shallow lake margins. Could be confused with other herbfield ecosystems: SA5 (exposed coast), SA1.4 (estuarine) or DN5.2 (dune slack), though this ecosystem is dominated by hydrophytes tolerant of submergence.
	Eutrophic- high fertility and weak acidity to weak alkalinity [Swamps and marshes].	Depressions and terraces with recent and organic soils.	WL18	Flaxland	Harakeke usually with toetoe, kiokio, species of *Carex*, *Machaerina*, and scattered cabbage tree, *Coprosma* spp. and mānuka	**Flax-dominated freshwater wetland**. Later successional examples may be dominated by cabbage trees.
		Depressions and lake and lagoon margins with recent and organic soils.	WL19	Raupō reedland	**Raupō**, locally with purua grass, lake clubrush, jointed twig rush, toetoe, pūkio, swamp millet.	**Raupō-dominated freshwater wetland**. Includes modified wetland examples where *Carex* spp, *Juncus* spp and swamp millet are common.
Estuarine	Salinity >5 % associated with tides or in lagoons.	River mouths, inlets, estuaries, and lagoons with sulphuric gley and recent gley soils, locally with shell and or gravel barrier beaches.	SA1.1	**Sea grass** On low-lying mud or sandy-silt flats, where tidal inundation is longest	Sea grass.	Presence of sea grass.

INDIGENOUS TERRESTRIAL AND WETLAND ECOSYSTEMS OF AUCKLAND

Table 4: Wetland ecosystems continued

Ecosystem drivers			Ecosystem unit		Diagnostic species	Diagnostic features
Hydrosystem	Fertility or chemistry	Landform	Code	Ecosystem name		
			SA1.2	**Mangrove forest and scrub** In areas of frequent tidal inundation where silt deposition is abundant near stream and rivers mouths	Mangrove.	Presence of mangroves
			SA1.3	**Sea rush and oioi Upper estuarine zone** where salt and freshwater dilution is greatest [Saltmarsh]	Sea rush and oioi.	Presence of sea rush and oioi within estuarine ecosystem. May grade into WL10 in freshwater zones at stream mouths. Differentiate based on hydrology and species mix.
			SA1.4	Halophytic herbfield (In depressions where salt water low-lying pools, and subsequently evaporates creating hypersaline conditions)	Glasswort, sea primrose and sea blite.	**Estuarine herbfield.** Could be confused with other herbfield ecosystems: SA5 (exposed coast), WL15.2 (lakeshore margins) or DN5.2 (dune slack). Differentiated by location (estuarine).
			SA1.7:	**Basaltic lava rockland/ coastal needle grass tussockland**	Coastal needle grass, oioi, knobby clubrush, glasswort, shore celery and shore lobelia.	Coastal needle grass tussockland occupies the saline margin of lava flows between the sea (often mangrove scrub) and pōhutukawa forest, typically at, or slightly above, mean high water springs. Largely restricted to Rangitoto Island and Anns Creek.

Table 5: Saline ecosystems

Temperature and humidity	Landform and soils	Salinity	Code	Ecosystem name		
Warm and sub-humid	Shell barrier beaches (formed from dead mollusc shells and sand forming long and narrow ridges)	Atmospheric salinity (e.g., spume and salt-spray) associated with persistent wind and occasional spring tide and storm surge inundation	SA1.5	**Shell-barrier beaches** [Chenier Plains]	Shellfield with occasional glasswort, *Austrostipa stipoides*, knobby clubrush, sea rush, sea primrose, bachelor's button and *Suaeda novae-zelandiae*, oioi, saltmarsh ribbonwood and tauhinu.	Auckland examples include shell/sandy spits at Shoal Bay, Ngataringa Bay, Hobson Bay, Tahuna Torea, Pollen Island, and in the Okura and Weiti River estuaries. There are other small spits in Auckland harbours and estuaries, e.g. within Kaipara Harbour. See Table 4 for other estuarine ecosystem variants.
	Beach ridges with raw estuarine soils (silt, sand, mollusc shells, gravel and locally with driftwood)	Atmospheric salinity (e.g., spume and salt-spray) associated with persistent wind and occasional spring tide and storm surge inundation.	SA1.6	**Coastal scrub On low mounds and estuarine margins**	Salt marsh ribbonwood, harakeke, coastal tree daisy and locally grading into ngaio, kōwhai, mānuka and cabbage tree.	Scrub on estuarine margins and on raised mounds within estuaries.
	Beach ridges with raw, stony and shingle soils, locally with driftwood	Atmospheric salinity (e.g., spume and salt-spray) associated with persistent wind.	SA4	Shore bindweed, knobby clubrush gravelfield/ stonefield	Gravelfield/stonefield locally with glasswort, half star, shore celery, knobby clubrush and shore bindweed.	Extremely rare in Auckland. Herbfield above MHWS on **gravel and boulder beaches.** Two known Auckland sites on Waiheke and two at Matingarahi. Probably on LBI and GBI.

INDIGENOUS TERRESTRIAL AND WETLAND ECOSYSTEMS OF AUCKLAND

Table 5: Saline ecosystems continued

Ecosystem drivers			Ecosystem unit		Diagnostic species	Diagnostic features
Temperature and humidity	**Landform and soils**	**Salinity**	**Code**	**Ecosystem name**		
	Marine terraces, hill-slopes, rocks, and cliffs rarely with marine mammal disturbance	Atmospheric salinity (e.g., spume and salt-spray) associated with persistent wind. Soils contain high concentrations of soluble salts.	SA5	Herbfield **[Coastal turf]**	Half star, sea primrose, *zoysia*, native spinach, ice plant, shore lobelia, NZ celery, dichondra, glasswort, shore groundsel and New Zealand sea spurrey.	Herbfield (turf) on shoreline rock landforms and, infrequently, on consolidated sand and gravel. Exposed to persistent wind and heavy salt deposition. Could be confused with SA1.4 (estuarine herbfield) or WL15.1 (ephemeral herbfield on coastal lakeshore margins), but SA5 **does not occur within estuaries or on lakeshore or lagoon margins**.
	Coastal hill-slopes and cliffs with seabird disturbance. Guano-enhanced soil fertility	Atmospheric salinity (e.g., spume and salt-spray) associated with persistent wind.	SA7	Iceplant, glasswort herbfield/loamfield	Seabird burrows and bare ground with herbfield of glasswort, iceplant, pigweed, shore groundsel, sea primrose, New Zealand celery amongst scrub of taupata, houpara, harakeke, ngaio and coastal māhoe.	Rare on Auckland mainland. Scrub and herbfield on coast in **seabird nesting areas**. Also known colloquially as petrel scrub.

***See other estuarine ecosystem types in Table 4 (above).**

Table 6: Dune ecosystems

Ecosystem drivers			Ecosystem unit		Diagnostic species	Diagnostic features
Physical and climatic disturbance	**Salinity**	**Landform**	**Code**	**Ecosystem name**		
Wind ablation	Atmospheric salinity (e.g., spume and salt-spray)	Erosion and accretion of sand resulting in dunes with raw sandy soils	DN2	Spinifex, pīngao grassland/sedgeland	**Spinifex** and **pīngao**, locally with sand tussock and shore bindweed and, further inland, sand coprosma, tauhinu, sand daphne and small-leaved pohuehue.	Active dune ecosystems dominated by spinifex and pīngao.
		Dune plains, damp sand plains, exposed coastal hill slopes and ridges, and rock stacks with raw sandy soils	DN5.1	Oioi, knobby clubrush sedgeland	Oioi, knobby clubrush, harakeke, toetoe.	Typically associated with rapidly accreting coastlines and formed behind mobile dunes where dune plains have formed. Oioi and knobby clubrush common.
		Recent deflation hollows and stream terraces with seasonally high water table and raw sandy soil [dune slack]	DN5.2	Herbfield [Dune slack]	Sand spike sedge, mudwort, *Lilaeopsis novae-zelandiae*, slender clubrush, sand tussock.	Ephemeral wetlands formed between sand ridges.

Table 7: Geothermal ecosystems

Ecosystem drivers			Ecosystem unit		Diagnostic species	Diagnostic features
Temperature	**Hydrology**	**Landform**	**Code**	**Ecosystem name**		
Soil and associated ground water with temperatures >20°C associated with geothermal heat	Water and steam of a range of temperature, pH and chemistry.	Geysers, pools, springs, streams, fumaroles, and sinter terraces (including their margins).	GT2	Geothermally-heated water and steam	Algae, fungi, bryophytes, invertebrates, bacteria, archaebacteria, cyanobacteria, diatoms, tasmanitids and amoeba.	Found in areas influenced by geothermal activity, e.g. Kaitoke Hot Springs, GBI.

INDIGENOUS TERRESTRIAL AND WETLAND ECOSYSTEMS OF AUCKLAND

Table 8: Cave ecosystems

Ecosystem drivers			Ecosystem unit		Diagnostic species	Diagnostic features
Solar radiation deficiency	**Temperature**	**Landform**	**Code**	**Ecosystem name**		
Lacking solar energy and associated photosynthetic energy inputs.	Low temperature fluctuation producing near constant atmospheric conditions.	Basaltic lava caves.	CV1	Subterranean rockland, stonefield	Detritivorous and predatory organisms, both epigean and specialist troglobites including species of molluscs, flies, glow worms, spiders, ground beetles, pseudo-scorpions and amphipods.	Found within caves

Table 9: Anthropogenic ecosystems

Ecosystem drivers			Ecosystem unit		Diagnostic species	Diagnostic features
Pastoral grazing [Anthropogenic succession]	**Temperature and humidity**	**Landform**	**Code**	**Ecosystem name**		
Disturbance associated with pastoral grazing	Warm to cool temperate and semi-arid to sub-humid	Moderately steep pastoral hill country of low to moderate fertility and localised areas on alluvial soils	AVS1	**Anthropogenic tōtara forest**	Tōtara is the dominant coloniser, often with kānuka and locally mānuka, and also kahikatea in humid areas. Kānuka and mānuka is frequently suppressed as stands mature. **Minimal understorey due to grazing.**	**Forest within a pastoral landscape** (typically develops in unfenced areas grazed by stock). **Tōtara is dominant** with minimal other diversity. Common in hill country in Rodney and parts of Mānukau Ecological District, also localised areas on alluvial soils. Over time can transition to other forest ecosystem types once fenced and if seed sources are available. Classify as treeland (TL) if tree and shrub cover is <80%.

Table 10: Additional ecosystem categories

Ecosystem type & code	Description	Variants	Notes
Treeland-TL	Treeland - Tree canopy cover 20-80%, tree cover exceeding that of any other growth form, but tree canopy discontinuous above lower non-woody vegetation. NB: Forest is defined as > 80% canopy cover of trees and shrubs.	TL.1: native-dominated treeland	Native-dominated: >75% native tree cover (NB: % relates to tree cover not overall cover across all tiers).
		TL.2: mixed native/exotic treeland	Mixed native/exotic: with 25-75% native tree cover (NB: % relates to tree cover not overall cover across all tiers).
		TL.3: exotic-dominated treeland	Exotic-dominated: <25% native with exotic tree cover dominant (NB: % relates to tree cover not overall cover across all tiers).
Exotic Forest-EF	Forest vegetation with >50% cover of exotic species in the canopy	EF.1 with >50% native understorey and/or groundcover biomass	Use this category when exotic canopy species are dominant.
		EF.2 with <50% native understorey and/or groundcover biomass	
Exotic Scrub-ES	Exotic secondary scrub or shrubland with >50% cover/biomass of exotic species.		Exotic species are dominant (>50% cover or biomass) and the future trajectory is uncertain.

INDIGENOUS TERRESTRIAL AND WETLAND ECOSYSTEMS OF AUCKLAND

Table 10: Additional ecosystem categories continued

Ecosystem type & code	Description	Variants	Notes
Exotic Grassland -EG	Grassland dominated by exotic species		Grassland dominant. Minimal cover/biomass from plants in any other vegetation tier.
Exotic Wetland -EW	Wetland ecosystems with >50% exotic plant biomass. Wetlands with exotic-dominated canopy (e.g. crack willow) but >75% native understorey/groundcover should be categorised as appropriate native wetland ecosystem type.		
Planted vegetation -PL	Native restoration plantings with <50% exotic biomass, or exotic and/or native amenity plantings.	P.1: planted native scrub and forest <20 years old or wetland <10 years old. P.2: planted native scrub and forest >20 years old or wetland >10 years old. P.3: native and/or amenity plantings.	
Brown Field - BF	Industrial zones, metalled carparks, rail corridors, unmanaged or managed land within urban settings, road median strips, pavements, cracks in concrete.	BF.1: largely exotic herbfield with some native herbaceous species may have occasional exotic or native woody species. BF.2: exotic herbfield.	Throughout the urban zone commonly thought of as wasteland. Substrate includes metal (stone chip) and concrete surfaces.

Glossary of plant names

Throughout the text, common plant names have been used where possible. The following alphabetical list gives the botanical name alongside these common names. Those marked with an asterisk (*) are non-native species.

Note that the ecosystems listed beside species names indicate where particular species are mentioned in the guide. They may not be the only ecosystem types where these species occur.

Nomenclature follows: Common names: Nichol, E.R. 1997. Common names of plants in New Zealand. Manaaki Whenua Press, Lincoln, Canterbury, New Zealand.

Scientific names: de Lange & Rolfe (2010) New Zealand indigenous vascular plant checklist 2010. New Zealand Plant Conservation Network.

Common Name	Scientific Name	Ecosystems
***African clubmoss**	*Selaginella kraussiana*	WF8, WF11, WF13
***agapanthus**	*Agapanthus praecox* subsp. *orientalis*	CL1
akeake	*Dodonaea viscosa*	SA4
akepiro	*Olearia furfuracea*	VS1
***alder**	*Alnus glutinosa*	WL12, WL15
***alligator weed**	*Alternanthera philoxeroides*	WL19
arrow grass	*Triglochin striata*	SA1, SA4, DN5, GT2
azolla	*Azolla rubra*	WL19
bamboo rush	*Sporadanthus ferrugineus*	WL1, WL3
***banana passionfruit**	*Passiflora* spp.	VS5
***bangalow palm**	*Archontophoenix cunninghamiana*	WF9, WF11, WF13
bachelor's button	*Cotula coronopifolia*	SA1
***beggars' ticks**	*Bidens frondosa*	WL19
***blackberry**	*Rubus fruticosus* agg.	WL2, VS3
bladderwort	*Utricularia* spp.	WL3
***blueberry**	*Vaccinium corymbosum*	WL2, WL3
bog pine	*Halocarpus bidwillii*	WL12
***boneseed**	*Chrysanthemoides monilifera* subsp. *monilifera*	CL1
bracken	*Pteridium esculentum*	DN2
broadleaf	*Griselinia littoralis*	MF25, CL6, VS2, VS5
broad-leaved poa	*Poa anceps*	CL6
***broom**	*Cytisus scoparius*	CL6, VS2, VS3, VS5
***buck's horn plantain**	*Plantago coronopus*	SA5
***buddleia**	*Buddleja davidii*	CL6
button daisy, cotula	*Leptinella* spp.	SA5, DN5
cabbage tree	*Cordyline australis*	WL18, DN2, VS5

Image left: Kidney fern. **John Sawyer.**

Common Name	Scientific Name	Ecosystems
centella	*Centella uniflora*	SA5
christella	*Christella dentata*	GT2
clubrush	*Isolepis* spp.	WL15, WL19, DN5, CL1
coastal astelia	*Astelia banksii*	CL1, VS1
coastal cutty grass	*Cyperus ustulatus*	DN5, GT2
coastal needle grass	*Austrostipa stipoides*	SA1
coastal tree daisy	*Olearia solandri*	DN2, SA1
coastal tussock	*Chionochloa bromoides*	CL1
***cordgrass**	*Spartina* spp.	SA1
***cotoneaster**	*Cotoneaster* spp.	CL6, VS3
***crack willow**	*Salix fragilis*	WL15, WL18
cress, scurvy grass	*Lepidium* spp.	SA7
dichondra	*Dichondra repens*	SA5
dracophyllum	*Dracophyllum* spp.	WL1
duckweed	*Lemna* spp.	WL19
eelgrass	*Zostera muelleri* subsp. *novozelandica*	SA1
***evergreen buckthorn**	*Rhamnus alaternus*	CL1
five-finger	*Pseudopanax arboreus*	VS2, VS5
***floating sweetgrass**	*Glyceria maxima*	WL11, WL19
forget-me-not	*Myosotis* spp.	SA5
geranium	*Geranium* spp.	DN5
***ginger**	*Hedychium gardnerianum*	WF9, WF11, WF13
glasswort	*Sarcocornia quinqueflora*	SA1, SA4, SA5, SA7
***gorse**	*Ulex europaeus*	WL1, CL1, CL6, VS2, VS3, VS5
greater wire rush	*Empodisma robustum*	WL2, WL3, WL11
***grey willow**	*Salix cinerea*	WL2, WL10, WL18
gumland grass tree	*Dracophyllum lessonianum*	WL3
gunnera	*Gunnera* spp.	DN5
***hakea**	*Hakea* spp.	WL1, VS3
half star	*Selliera radicans*	SA1, SA4, SA5, WL15, DN5, CL1
Hall's tōtara	*Podocarpus cunninghamii*	MF25
hangehange	*Geniostoma ligustrifolium*	VS3
harakeke, flax	*Phormium tenax*	SA4, SA7, WL10, WL11, WL18, WL19, DN2,
hard beech	*Nothofagus truncata*	WF4, WF12
***hawkbit**	*Leontodon taraxacoides*	WL15
hebe	*Veronica* spp.	SA7, CL1, CL6, VS1, VS5
***Himalayan honeysuckle**	*Leycesteria formosa*	VS5
hīnau	*Elaeocarpus dentatus*	WF5, WF9, WF10, WF12, WF13, MF24, MF25
Holloway's crystalwort	*Atriplex hollowayi*	DN2
houpara	*Pseudopanax lessonii*	CL1
hutu	*Ascarina lucida* var. *lucida*	MF25, MF24
***ivy**	*Hedera helix* subsp. *helix*	CL6
***Japanese honeysuckle**	*Lonicera japonica*	VS3, VS5
***Japanese walnut**	*Juglans ailantifolia*	WL10
jersey cudweed	*Pseudognaphalium luteoalbum*	DN5
jointed twig rush	*Machaerina articulata*	WL19
kahikatea	*Dacrycarpus dacrydioides*	WF7, WF8, WF9, WF11, WF13, MF4, WL18, AVS1

INDIGENOUS TERRESTRIAL AND WETLAND ECOSYSTEMS OF AUCKLAND

Common Name	Scientific Name	Ecosystems
kaikawaka	*Libocedrus bidwillii*	MF25
kaikōmako	*Pennantia corymbosa*	MF4, VS5
kāmahi	*Weimannia racemosa*	WF12, WF13, VS5
kanono	*Coprosma grandifolia*	VS5
kānuka	*Kunzea* spp.	WF4, WF5, DN2, CL6, VS2, VS3, VS5, AVS1
karaka	*Corynocarpus laevigatus*	WF4, WF5, WF7, WF9, CL1
karamū	*Coprosma robusta*	VS2, VS5
karo	*Pittosporum crassifolium*	SA4, CL1
kauri	*Agathis australis*	WF4, WF10, WF11, WF12, MF25
kauri grass	*Astelia trinervia*	WF10
kawakawa	*Piper excelsum*	CL1, VS3
kidney fern	*Cardiomanes reniforme*	MF25
kiekie	*Freycinetia banksii*	WF8, WF10
kiokio	*Blechnum* spp.	WL18
Kirk's daisy	*Brachyglottis kirkii* var. *kirkii*	VS1
knobby clubrush	*Ficinia nodosa*	SA1, SA4, DN5, CL1
kohekohe	*Dysoxylum spectabile*	WF4, WF5, WF7, WF8, WF9, WF10, WF11, WF12, WF13, CL1
kōhūhū	*Pittosporum tenuifolium*	VS2
koromiko	*Hebe stricta*	VS1
kōtukutuku	*Fuchsia excorticata*	VS5
kōwhai	*Sophora* spp.	WF4, WF7, SA4, CL6, VS2, VS5
kūmerahou	*Pomaderris kumeraho*	WL1.2
kuta	*Eleocharis sphacelata*	WL10, WL11, WL19
lacebark	*Hoheria populnea*	MF4, VS5
lake clubrush	*Schoenoplectus tabernaemontani*	WL10, WL11, WL19
lancewood	*Pseudopanax crassifolius*	VS2
lemonwood	*Pittosporum eugenioides*	MF4
***lodgepole pine**	*Pinus contorta*	WL12
***lotus**	*Lotus* spp.	SA5
***lupin**	*Lupinus* spp.	DN2, VS2
māhoe	*Melicytus ramiflorus*	WF5, WF8, MF4, VS2, VS3, VS5
maidenhair	*Adiantum* spp.	WF4, WF5, WF7, WF9, WF10, WF11, WF12, WF13, MF24, MF25, CV1
makamaka	*Ackama rosifolia*	WF9, MF24
mamaku	*Cyathea medullaris*	WF9, VS3, VS5
māmāngi	*Coprosma arborea*	VS5
***Manchurian rice grass**	*Zizania latifolia*	WL10, WL19
mangeao	*Litsea calicaris*	WF4, WF9, WF13, MF24
mangrove, manawa	*Avicennia marina* subsp. *australasica*	SA1
mānuka	*Leptospermum scoparium*	WL1, WL2, WL3, WL11, WL18, DN2, DN5, CL6, VS3, VS5, AVS1
mapere	*Gahnia xanthocarpa*	WF8
māpou	*Myrsine australis*	WF5, VS3, VS5
***marram**	*Ammophila arenaria*	DN2
marsh fern	*Thelypteris confluens*	GT2
matagouri	*Discaria toumatou*	DN2

Common Name	Scientific Name	Ecosystems
mataī	*Prumnopitys taxifolia*	WF7, MF4,
***mercer grass**	*Paspalum distichum*	WL15
***Mexican daisy**	*Erigeron karvinskianus*	CL1, CL6
miro	*Prumnopitys ferruginea*	WF9, WF10, WF11, WF12, WF13, MF24, MF25
monoao	*Halocarpus kirkii*	WF10, MF25
***monkey apple**	*Syzygium smithii*	WF9, WF11
***moth plant**	*Araujia sericifera*	CL1
***mouse-ear chickweed**	*Cerastium fontanum*	WL15
mountain daisy	*Celmisia* spp.	CL6
mountain five-finger	*Pseudopanax colensoi*	MF25
mudwort	*Limosella* spp.	WL15, DN5
narrow-leaved maire	*Nestegis montana*	WF5, WF12
native spinach	*Tetragonia* spp.	SA5
needle-leaved neinei	*Dracophyllum latifolium*	WF10
nertera	*Nertera* spp.	SA5
New Zealand broom	*Carmichaelia* spp.	CL1, CL6
New Zealand celery	*Apium prostratum*	SA7
New Zealand daphne	*Pimelea* spp.	SA4, CL6
New Zealand ice plant	*Disphyma australe* subsp. *australe*	SA7, CL1
New Zealand sea spurrey	*Spergularia tasmanica*	SA5
ngaio	*Myoporum laetum*	WF4, WF5, SA4, SA7, CL6, VS5
nīkau	*Rhopalostylis sapida*	WF4, WF7, WF9, WF13
northern rātā	*Metrosideros robusta*	WF7, WF9, WF10, WF11, WF12, WF13, MF24
oioi	*Apodasmia similis*	SA1, WL10, WL11, DN5, GT2
***old man's beard**	*Clematis vitalba*	CL6, VS5
***pampas**	*Cortaderia* spp.	CL1, CL6
parataniwha	*Elatostema rugosum*	WF8
Parkinson's rātā	*Metrosideros parkinsonii*	MF25
patē	*Schefflera digitata*	VS5
pennywort	*Hydrocotyle* spp.	WL15, DN5
peperomia	*Peperomia urvilleana*	VS1
perching lily	*Astelia solandri*	CL6
pigweed	*Chenopodium* spp.	SA7, CL1
pin cushion	*Colobanthus* spp.	DN5
***pine**	*Pinus* spp.	WL1, CL1, CL6, VS2, VS3
pīngao	*Ficinia spiralis*	DN2
pink pine	*Halocarpus biformis*	WL12
plantain	*Plantago* spp.	WL15
poa	*Poa* spp.	SA7
poataniwha	*Melicope simplex*	MF4
pōhuehue	*Muehlenbeckia* spp.	SA4
pōhutukawa	*Metrosideros excelsa*	WF4, WF5, SA4, CL1
pōkākā	*Elaeocarpus hookerianus*	MF4
pondweed	*Potamogeton* spp.	WL15, WL19
ponga	*Cyathea dealbata*	VS3, VS5
Poor Knights lily	*Xeronema callistemon*	CL1

Common Name	Scientific Name	Ecosystems
prickly mingimingi	*Leptecophylla juniperina*	VS2
***privet**	*Ligustrum* spp.	WF13, VS2, VS3, VS5
puka	*Griselinia lucida*	WF4, CL1, VS1
pukatea	*Laurelia novae-zelandiae*	WF7, WF8, WF9, WF11, WF13, MF4, MF24
pūkio	*Carex secta, C. virgata*	WL18, WL19
pūriri	*Vitex lucens*	WF4, WF5, WF7, WF9, WF11, WF13
pūrua grass	*Bolboschoenus* spp.	WL10, WL19
putaputawētā	*Carpodetus serratus*	VS2, VS5
quintinia	*Quintinia serrata*	MF25
rangiora	*Brachyglottis repanda*	VS5
rātā lianes	*Metrosideros* spp.	CL6
raukawa	*Raukaua edgerleyi*	WF9, MF24
raupō	*Typha orientalis*	WL10, WL18, WL19
***reed canary grass**	*Phalaris arundinacea*	WL19
rengarenga lily	*Arthropodium cirratum*	CL1
rewarewa	*Knightia excelsa*	WF4, WF5, WF7, WF9, WF10, WF11, WF12, WF13, MF24, VS3
ribbonwood	*Plagianthus regius*	VS5
rimu	*Dacrydium cupressinum*	WF8, WF9, WF10, WF11, WF12, WF13, MF24, MF25,
round-leaved coprosma	*Coprosma rotundifolia*	MF4
***royal fern**	*Osmunda regalis*	WL2
rush	*Juncus* spp.	WL11
salt-marsh ribbonwood	*Plagianthus divaricatus*	SA1
***saltwater paspalum**	*Paspalum vaginatum*	SA1
sand coprosma	*Coprosma acerosa*	DN2
sand daphne	*Pimelea villosa*	DN2
sand musk	*Mazus* spp.	SA5
sand sedge	*Carex pumila*	DN2, DN5
sand tussock	*Poa billardierei*	DN2
***sand wattle**	*Acacia longifolia*	DN2
scabweed	*Raoulia* spp.	DN5
***scarlet pimpernel**	*Anagallis arvensis* subsp. *arvensis* var. *arvensis*	WL15
sea blite	*Suaeda novae-zelandiae*	SA1
***sea couch**	*Elytrigia pycnantha*	SA1
sea grass	*Zostera muelleri* subsp. *novazelandica*	SA1
sea primrose	*Samolus repens*	SA1, SA5, SA7
sea rush	*Juncus krausii* var. *australiensis*	SA1
sharp spike sedge	*Eleocharis acuta*	WL11
shining karamū	*Coprosma lucida*	VS5
shore bindweed	*Calystegia soldanella*	SA4, DN2
shore celery	*Apium prostratum*	SA4, SA5, SA7, CL1
shore groundsel	*Senecio lautus* subsp. *lautus*	SA5, SA7
shore lobelia	*Lobelia anceps*	SA5
shore spurge	*Euphorbia glauca*	SA4
***sickle grass**	*Parapholis incurva*	SA1
silver pine	*Manoao colensoi*	WL1, WL2

Common Name	Scientific Name	Ecosystems
silver tussock	*Poa cita*	DN5
Sinclair's tamingi	*Epacris sinclairii*	WL3
slender clubrush	*Isolepis cernua*	SA5, CL1
small-leaved pōhuehue	*Muehlenbeckia complexa*	SA4, SA7, DN2
snowberry	*Gaultheria* spp.	CL6
snow tussock	*Chionochloa flavicans*	CL6
soft tree fern	*Cyathea smithii*	VS5
southern rātā	*Metrosideros umbellata*	MF25, VS5
***Spanish heath**	*Erica lusitanica*	WL1
sphagnum	*Sphagnum cristatum*	WL2, WL3
spinifex	*Spinifex sericeus*	DN2
square sedge	*Lepidosperma australe*	WL11, DN5
sundew	*Drosera* spp.	WL3
supplejack	*Ripogonum scandens*	WF8
swamp astelia	*Astelia grandis*	WF8
swamp helmet orchid	*Corybas carsei*	WL3
swamp maire	*Syzygium maire*	MF24, WF8, WF9
swamp māhoe	*Melicytus micranthus*	MF4
swamp millet	*Isachne globosa*	WL19
swamp twig rush	*Machaerina juncea*	SA1
***sycamore**	*Acer pseudoplatanus*	VS5
***tall fescue**	*Schedonorus arundinaceus*	DN5
tall mingimingi	*Leucopogon fasciculatus*	CL6, VS2
tamingi	*Epacris pauciflora*	WL1, WL2
tānekaha	*Phyllocladus trichomanoides*	WF4, WF10, WF11, WF12, SA4
tangle fern	*Gleichenia* spp.	WL2, WL3, WL11
tank lily	*Astelia hastata*	CL6
taraire	*Beilschmiedia tarairi*	WF4, WF5, WF7, WF8, WF9, WF10, WF11
tauhinu	*Ozothamnus leptophyllus*	SA4, DN2, VS2
taupata	*Coprosma repens*	SA4, SA7, CL1
tawa	*Beilschmiedia tawa*	WF4, WF5, WF7, WF8, WF9, WF10, WF11, WF12, WF13, MF24
tāwari	*Ixerba brexioides*	WF9, WF12, MF24, MF25
tawāpou	*Pouteria costata*	WF4, CL1
tāwheowheo	*Quintinia serrata*	MF25
thin-barked tōtara	*Podocarpus laetus*	WF10, WF11, WF12, MF25
three-finger	*Pseudopanax colensoi* var. *colensoi*	MF25
tītoki	*Alectryon excelsus*	WF4, WF5, WF7, WF8, MF4
toatoa	*Phyllocladus toatoa*	WF10, MF25
toetoe	*Austroderia* spp.	WL18, WL19, DN2, DN5, CL1
toru	*Toronia toru*	WL1.2
tōtara	*Podocarpus tōtara*	WF5, WF7, WF10, WF11, WF12, WF13, VS2, AVS1
tōwai	*Weinmannia silvicola*	WF9, WF10, WF11, WF12, WF13, MF24, MF25
***tradescantia**	*Tradescantia fluminensis*	WF8, WF9, WF11
tree daisy	*Olearia* spp.	CL6, VS5

Common Name	Scientific Name	Ecosystems
***tree privet**	*Ligustrum lucidum*	VS1, VS2, VS3, VS5
tūrepo	*Streblus banksii*	MF4, CL1
***turf speedwell**	*Veronica serpyllifolia*	WL15
tūrutu	*Dianella nigra*	CL6
tutu	*Coriaria* spp.	DN2, CL6, VS5
twiggy tree daisy	*Olearia virgata*	WL18,
violet	*Viola* spp.	WL15
Waitākere rock koromiko	*Veronica bishopiana*	CL6
***water celery**	*Apium nodiflorum*	WL19
water milfoil	*Myriophyllum* spp.	WL15, WL19
***water pepper**	*Persicaria hydropiper*	WL18
***water purslane**	*Ludwigia palustris*	WL19
***water speedwell**	*Veronica anagallis-aquatica*	WL19
***wattle**	*Acacia* spp.	VS2, VS3
weeping matipo	*Myrsine divaricata*	WL18
wharangi	*Melicope ternata*	CL1
wharariki	*Phormium cookianum*	CL6
whekī-ponga	*Dicksonia fibrosa*	VS5
whisk fern	*Psilotum nudum*	GT2
willowherb	*Epilobium* spp.	SA5, WL18, WL19, DN5
wineberry	*Aristotelia serrata*	VS5
woollyhead	*Craspedia* spp.	DN5
***woolly nightshade**	*Solanum mauritianum*	CL1
yellow-silver pine	*Lepidothamnus intermedius*	MF25
***Yorkshire fog**	*Holcus lanatus*	DN5
zoysia	*Zoysia* spp.	SA5

Species without common names.

Scientific Name	Ecosystems
Archeria racemosa	WF10
Astelia spp.	MF25
Carex spp.	WL11, WL15, WL18
Centipeda spp.	WL15
Centrolepis spp.	WL15
Coprosma spp.	SA4, WL11, WL18, VS3
Coprosma rhamnoides	VS2
Corybas carsei	WL3
Crassula spp.	SA5, WL15
Cyclosorus interruptus	GT2
Dracophyllum spp.	MF25, WL1, CL6
Eleocharis spp.	WL11, WL15, WL19
Gahnia spp.	MF25, WL1, WL11
Glossostigma elatinoides	WL15
Hydrocotyle novae-zeelandiae	SA5
Isolepis prolifer	WL18
Lachnagrostis spp.	WL15
Lepidosperma spp.	WL1, WL11, DN5

Species without common names continued.

Scientific Name	Ecosystems
Leptinella rotundata	CL1
Lilaeopsis novae-zelandiae	WL15, DN5
Limosella lineata	WL15, DN5
Lobelia spp.	WL15, DN5
Lycopodiella lateralis	WL3
Machaerina spp.	WL1, WL2, WL3, WL10, WL11, WL18, WL19,
Machaerina tenax	WL2
Machaerina arthrophylla	WL11
Machaerina rubiginosa	WL11
Machaerina teretifolia	WL3
Melicytus spp.	SA4, SA7
Myriophyllum votschii	DN5
Pittosporum spp.	VS3, VS5
Pseudopanax spp.	VS3, VS5
Ranunculus spp.	SA5, WL15, WL18, WL19, DN5
Schoenus spp.	WL1, WL2, WL3
Schoenus brevifolius	WL2
Schoenus pauciflorus	WL12
Schoenus tendo	VS2
Sticherus flabellatus var. *flabellatus*	GT2
Tetraria spp.	WL1
Tetraria capillaris	WL1, WL2

Image right: Ruru. **Alastair Jamieson.**

Glossary of fauna names

Nomenclature follows: Hitchmough *et al.* (2013), Gill (2010), O'Donnell *et al.* (2009), King (1990), Worthy & Holdaway (2002)

adzebill		*Aptornis otidiformis*
amphibians	Archey's frog	*Leiopelma archeyi*
	Hochstetter's frog	*Leiopelma hochstetteri*
	extinct Leiopelmatid frog	*Leiopelma markhami*
	extinct Leiopelmatid frog	*Leiopelma waitomoensis*
	green frog	*Litoria aurea*
	golden bell frog	*Litoria raniformis*
Australasian bittern	*Botaurus poiciloptilus*	
banded rail	*Gallirallus philippensis*	
bat spp.	greater short-tailed bat	*Mystacina robusta*
	lesser short-tailed bat	*Mystacina tuberculata*
	long-tailed bat	*Chalinolobus tuberculatus*
bell frog spp.	green frog	*Litoria aurea*
	golden bell frog	*Litoria raniformis*
bellbird	*Anthornis melanura*	
black petrel	*Procellaria parkinsoni*	
blackbird	*Turdus merula*	
brown kiwi	*Apteryx mantelli*	
brown quail	*Coturnix ypsilophora*	
California quail	*Callipepla californica*	
cave wētā	*Gymnoplectron acanthocera*	
chaffinch	*Fringilla coelebs*	
Cook's petrel	*Pterodroma cookii*	
coot, extinct	*Fulica prisca*	
crakes	marsh crake	*Porzana pusilla*
	spotless crake	*Porzana tabuensis*
diving petrel	*Pelecanoides urinatrix*	
dotterel spp.	banded dotterel	*Charadrius bicinctus*
	New Zealand dotterel	*Charadrius obscurus*
duck spp	Australasian shoveler	*Anas rhynchotis*
	blue duck	*Hymenolaimus malacorhynchos*
	brown teal	*Anas chlorotis*
	Finsch's duck	*Chenonetta finschi*
	grey duck	*Anas superciliosa*
	grey teal	*Anas gracilis*
	New Zealand blue-billed duck	*Oxyura vantetsi*
	New Zealand musk duck	*Biziura delautori*
	paradise shelduck	*Tadorna variegata*
	southern merganser	*Mergus australis*

dunnock	*Prunella modularis*	
ephydrid fly	*Ephydrella thermarum*	
fairy tern	*Sterna nereis*	
fantail	*Rhipidura fuliginosa*	
fernbird	*Bowdleria punctata*	
flightless rails	Hodgen's waterhen	*Gallinula hodgenorum*
	snipe rail	*Capellirallus karamū*
	takahē	*Porphyrio mantelli*
	weka	*Gallirallus australis*
forest-inhabiting ducks	blue buck	*Hymenolaimus malacorhynchos*
	brown teal	*Anas chlorotis*
	Finsch's duck	*Chenonetta finschi*
gecko spp.	common gecko	*Woodworthia maculata*
	Duvaucel's gecko	*Hoplodactylus duvauceli*
	forest gecko	*Mokopirirakau granulatus*
	Pacific gecko	*Dactylocnemis pacificus*
	Auckland green gecko	*Naultinus elegans*
giant moa, North Island	*Dinornis novaezealandiae*	
glow worm	*Arachnocampa luminosa*	
grey warbler	*Gerygone igata*	
grey-faced petrel	*Pterodroma macroptera*	
gull spp.	black-backed gull	*Larus dominicanus*
	black-billed gull	*Larus bulleri*
	red-billed gull	*Larus scopulinus*
heron spp.	reef heron	*Egretta sacra*
	white heron	*Ardea modesta*
	white-faced heron	*Egretta novaehollandiae*
hihi, stitchbird	*Notiomystis cincta*	
Hochstetter's frog	*Leiopelma hochstetteri*	
house sparrow	*Passer domesticus*	
huia	*Heteralocha acutirostris*	
invertebrates (e.g. wētā)	cave wētā	*Gymnoplectron acanthocera*
	giant wētā	*Deinacrida heteracantha*
	ground wētā spp.	*Hemiandrus* spp.
	tree wētā	*Hemideina thoracica*
	tusked wētā spp.	*Motuweta* spp.
kākā	*Nestor meridionalis*	
kākāpō	*Strigops habroptilus*	
kākāriki, red-crowned	*Cyanoramphus novaezelandiae*	
kākāriki, yellow-crowned	*Cyanoramphus auriceps*	
kererū	*Hemiphaga novaeseelandiae*	
kingfisher	*Todiramphus sanctus*	
kōkako, North Island	*Callaeas wilsoni*	
little bittern	*Ixobrychus novaezelandiae*	
little bush moa	*Anomalopteryx didiformis*	
little penguin	*Eudyptula minor*	
little spotted kiwi	*Apteryx owenii*	
long-tailed cuckoo	*Eudynamys taitensis*	
Mantell's moa	*Pachyornis geranoides*	

moa spp.	little bush moa	*Anomalopteryx didiformis*
	Mantell's moa	*Pachyornis geranoides*
	North Island giant moa	*Dinornis novaezealandiae*
	stout-legged moa	*Euryapteryx curtus*
morepork	*Ninox noveseelandiae*	
mottled petrel	*Pterodroma inexpectata*	
myna	*Acridotheres tristis*	
New Zealand falcon	*Falco novaeseelandiae*	
New Zealand quail	*Coturnix novaezelandiae*	
New Zealand raven	*Corvus antipodum*	
North Island goose	*Cnemiornis gracilis*	
owl spp.	laughing owl	*Sceloglaux albifacies*
	morepork	*Ninox novaeseelandiae*
owlet-nightjar	*Aegotheles novaezealandiae*	
oystercatcher spp.	pied oystercatcher	*Haematopus finschi*
	variable oystercatcher	*Haematopus unicolor*
pheasant	*Phasianus colchicus*	
piopio, North Island	*Turnagra tanagra*	
pipit	*Anthus novaeseelandiae*	
raptor spp.	Australasian harrier	*Circus approximans*
	Forbes' harrier	*Circus teauteensis*
	laughing owl	*Sceloglaux albifacies*
	morepork	*Ninox novaeseelandiae*
reef heron	*Egretta sacra*	
rifleman	*Acanthisitta chloris*	
robin, North Island	*Petroica longipes*	
rosella	*Platycercus eximius*	
saddleback, North Island	*Philesturnus rufusater*	
seal, NZ fur	*Arctocephalus forsteri*	
shag spp.	black shag	*Phalacrocorax carbo*
	little shag	*Phalacrocorax melanoleucos*
	little black shag	*Phalacrocorax sulcirostris*
	pied shag	*Phalacrocorax varius*
	spotted shag	*Stictocarbo punctatus*
shearwater spp.	Buller's shearwater	*Puffinus bulleri*
	flesh-footed shearwater	*Puffinus carneipes*
	fluttering shearwater	*Puffinus gavia*
	little shearwater	*Puffinus assimils*
	sooty shearwater	*Puffinus griseus*
shining cuckoo	*Chrysococcyx lucidus*	
shorebird spp. see wader spp.		
shore plover	*Thinornis novaeseelandiae*	
silvereye	*Zosterops lateralis*	
skink spp.	chevron skink	*Oligosoma homalonotum*
	copper skink	*Oligosoma aeneum*
	egg-laying skink	*Oligosoma suteri*
	McGregor's skink	*Oligosoma macgregori*
	moko skink	*Oligosoma moco*
	ornate skink	*Oligosoma ornatum*
	robust skink	*Oligosoma alani*
	shore skink	*Oligosoma smithi*
	striped skink	*Oligosoma striatum*

snipe	*Coenocorypha barriensis*	
song thrush	*Turdus philomelos*	
spoonbill, royal	*Platalea regia*	
starling	*Sturnus vulgaris*	
stout-legged moa	*Euryapteryx curtus*	
swallow	*Hirundo neoxena*	
swan, black	*Cygnus atratus*	
takahē	*Porphyrio mantelli*	
tern spp.	Caspian tern	*Hydroprogne caspia*
	fairy tern	*Sterna nereis*
	white-fronted tern	*Sterna striata*
tomtit	*Petroica macrocephala*	
tuatara	*Sphenodon punctatus*	
tūī	*Prosthemadera novaeseelandiae*	
wader spp.	banded dotterel	*Charadrius bicinctus*
	bar-tailed godwit	*Limosa lapponica*
	black stilt	*Himantopus novaezelandiae*
	golden plover	*Pluvialis dominica*
	lesser knot	*Calidris canutus*
	New Zealand dotterel	*Charadrius obscurus*
	pied oystercatcher	*Haematopus finschi*
	pied stilt	*Himantopus leucocephalus*
	shore plover	*Thinornis novaeseelandiae*
	turnstone	*Arenaria interpres*
	variable oystercatcher	*Haematopus unicolor*
	wrybill	*Anarhynchus frontalis*
waterhen, Hodgen's extinct	*Gallinula hodgenorum*	
white cockatoo	*Cacatua galerita*	
white-faced heron	*Egretta novaehollandiae*	
white-faced storm petrel	*Pelagodroma marina*	
whitehead	*Mohoua albicilla*	
wrens	bush wren	*Xenicus longipes*
	long-billed wren	*Dendroscansor decurvirostris*
	Lyall's wren	*Traversia lyalli*
	stout-legged wren	*Pachyplichas jagmi*

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