Indigenous terrestrial and freshwater ecosystems of Auckland

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Contents

1. Introduction

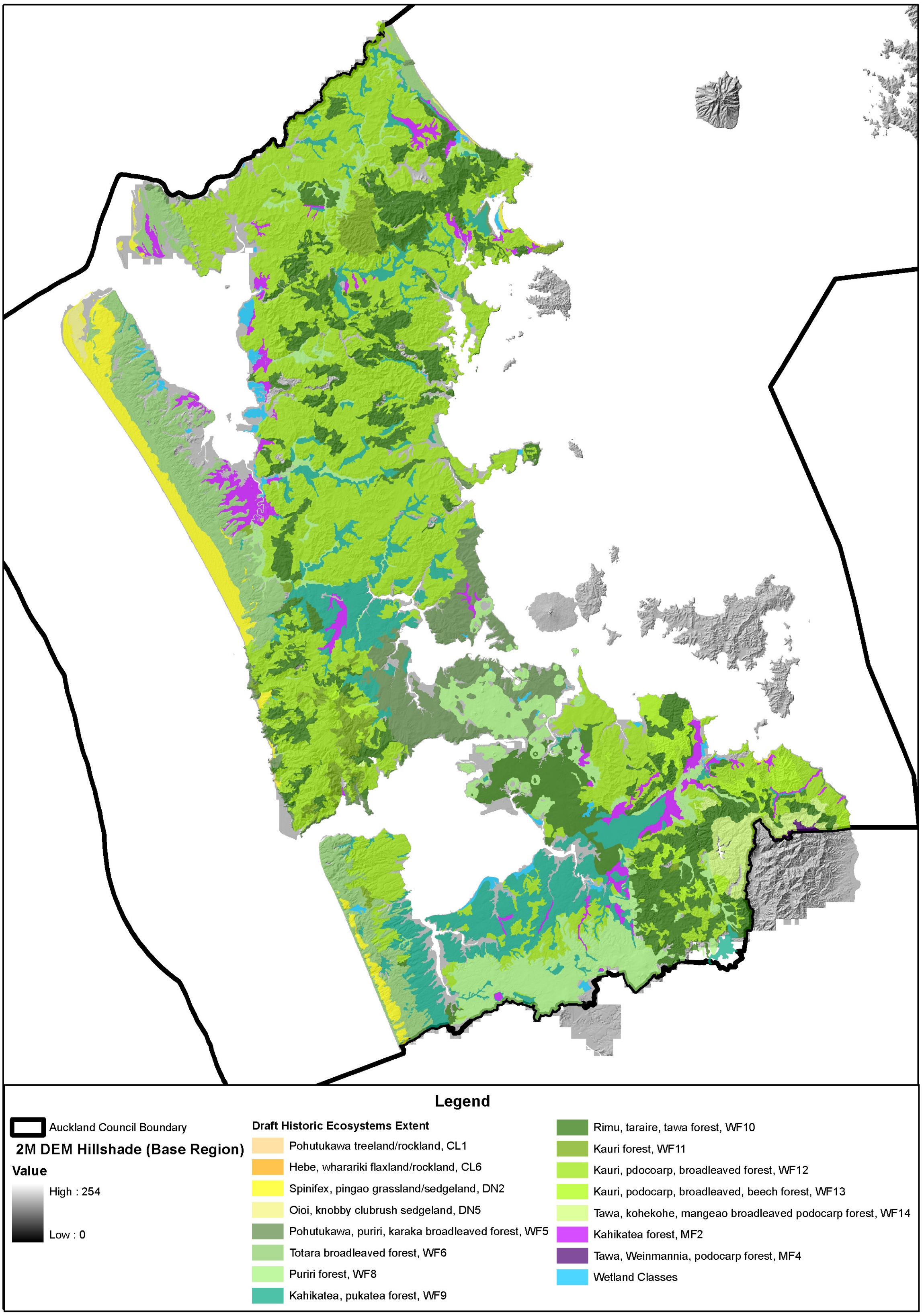
This report describes the 35 ecosystems, and their regional variants, that have been identified by Auckland Council as occurring in the Auckland region. Auckland Council has based this ecosystem work on the national ecosystem classification system developed by the Department of Conservation. The Department's staff Nick Singers, Geoff Rogers and John Leathwick developed an ecosystem classification system for New Zealand that builds on all published and unpublished classification systems (see Singers, Rogers and Leathwick in press). This includes research by McKelvey and Nichols (1959), Nichols (1976), Wardle (1991) and Williams et al (2007) and many others. 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.

An ecosystem is a biological community of interacting organisms and their physical environment. It is recognisable by its assemblage of plant species that interact with each other as well as with the elements of their environment and is distinct from adjacent assemblages. Ecosystems may vary in size from small ephemeral wetlands to large tracts of forest.

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

Map 1 shows the natural extent of indigenous terrestrial ecosystems in Auckland whereby the "natural extent" means a combination of our understanding of the historic pre-human diversity, distribution and extent of ecosystems in Auckland and what we would expect this to be given past and current environmental drivers.

The current distribution of each of the ecosystems in this report is shown in a separate Auckland Council publication entitled "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013). That map should be referred to when reading this report to provide detailed distribution information in the Auckland region.



Map 1: Natural extent of Auckland's terrestrial ecosystems. "Natural extent" is intended to mean a combination of our understanding of the historic pre-human diversity, distribution and extent of ecosystems in Auckland and what we would expect this to be given past and current environmental drivers.

2. Threatened ecosystems

Ecosystems around the world are facing unprecedented threats and this will affect biodiversity and the services that living organisms and their habitats provide to people, including the provision of clean water and both agricultural and fisheries productivity. This threat to ecosystem function has been identified as one of the world's most significant conservation challenges. A better system for understanding the risks to the world's ecosystems will enable more informed decisions to be made about sustainable environmental management.

The World Conservation Union (IUCN) has recently developed a new system for assessing the status of ecosystems (Keith et al. 2013). The method evaluates multiple symptoms of risk produced by different processes of ecosystem degradation including factors such as changes in the distribution of an ecosystem, its physical environment and its component species all of which indicate different aspects of the severity of the risks. The IUCN system allows all these symptoms to be assessed in standard ways across different types of ecosystem. The IUCN have suggested that this threat assessment of ecosystems will be of value to a number of different sectors (see Box 1)

Box 1: Benefits of the IUCN threat assessment of ecosystems

- *Conservation*: to help prioritise action 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 ecosystems 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.

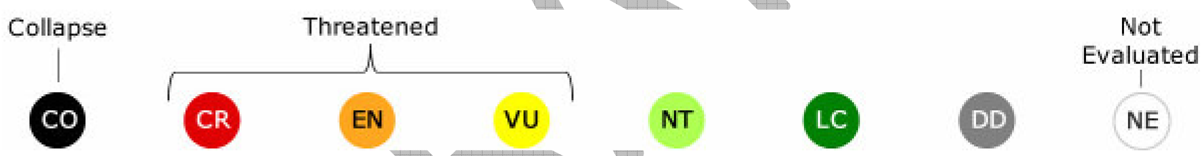
3. Threatened Ecosystem Assessments in Auckland

The Auckland region, like the rest of New Zealand is part of a terrestrial biodiversity hotspot 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 vegetation as a land cover, continued impact and increasing threat of invasive species and diseases, overharvesting, pollution and climate change (State of the Auckland Region report 2010). Many of Auckland's ecosystem types are thought to have been reduced from pre-human times to less than ten percent of their original extent and others are considered to have been naturally uncommon. To identify which of Auckland's ecosystems are threatened and to help with prioritisation of protection, management and restoration a thorough threatened ecosystem assessment was completed.

This report includes assessments of the regional conservation status of all of Auckland's 35 terrestrial ecosystem types, and their regional variants. They were evaluated using the International Union for the Conservation of Nature (IUCN) Red List of Ecosystems criteria. The criteria (Keith et al. 2013) are a global standard for assessing the status of ecosystems and are applicable at local, regional, national and global levels. The criteria determine the risk of ecosystem collapse, and are consistent and complementary to the IUCN Red List of Threatened Species.

The criteria were used to determine which ecosystems are at risk of loss of characteristic native biota, and thus are vulnerable, endangered, or critically endangered and at threat of collapse. Also, which ecosystem types are near threatened or not threatened at all (Least Concern).

The criteria include eight categories of risk for each ecosystem. 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. These are complemented by several qualitative categories that accommodate: 1) ecosystems that fail to meet the quantitative criteria for the threatened ecosystem categories (NT, Near Threatened); 2) ecosystems that unambiguously meet none of the quantitative criteria (LC, Least Concern); 3) ecosystems for which too few data exist to apply any criterion (DD, Data Deficient); and 4) 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 analogue of the extinct (EX) category for species.



To run the assessments, existing information and new field survey data was 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. weed and animal pest impacts)

The results of this regional threat assessment are shown at the start of each ecosystem description. These assessments provide vital insights into the state of Auckland's terrestrial ecosystems, guidance for statutory protection, and will help to prioritise active conservation management.

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Forest ecosystems

WF5: Pohutukawa–puriri–karaka broadleaved forest

IUCN Status: Critically Endangered

This broadleaved forest ecosystem occurs in parts of the coastal zone that receive winds and salt spray, predominantly within 600–800 m 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). Younger successional variants occur on recent lava flows and volcanic surfaces (e.g. Rangitoto Island).

Distribution: In frost-free areas from Three King Islands and Te Paki south to Mahia and New Plymouth, with outliers around some central North Island lakes. The southern boundary conforms to the southern limits of puriri, aligning approximately to the thermic soil temperature zone (Molloy 1998)[1].

Characteristic native biota: Broadleaved species dominate this forest, with pohutukawa, puriri, karaka and kohekohe most common and, locally, taraire, tawa, titoki, mangeao, rewarewa, puka, tawapou, ngaio and nikau. Kauri, kowhai species and kanuka may be present on dry ridges as well as, locally, tanekaha and hard beech (McKelvey & Nicholls 1959; Nicholls 1976; Esler 1983; Conning 2001). On some northern offshore islands, especially Three Kings, there are local endemic species and varieties. On recent surfaces resulting from volcanism (e.g. Rangitoto Island), successional examples largely dominated by pohutukawa occur, considered to be an early variant of this ecosystem. Sea birds are a feature though they are now largely restricted to predator-free islands.

Key processes and interactions: This ecosystem is largely dependent on a warm coastal climate. Most dominant species (e.g. puriri and kohekohe) have shade-tolerant seedlings and readily regenerate beneath the forest canopy. Others (e.g. pohutukawa), 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 sea birds 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 Maori and later European—with a large proportion burnt and cleared for agriculture. Many remaining examples are small and continue to suffer by being fragmented. On the mainland, there are few examples in a state of high ecological integrity, and many are reverting to something like their former composition (e.g. Waitakere coast). The best remaining examples occur on the northern

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[1] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

offshore islands, many of which are nature reserves, free of mammalian pests and subject to ongoing threat management.

Animal pests and a wide range of weeds are significant threats. Many common canopy species are highly palatable to possums and ungulates (e.g. pohutukawa and kohekohe). Continuing high numbers of pests will result in canopy collapse and regeneration failure, including dominant species such as puriri, pohutukawa and kohekohe. Predators, especially rats, can be prolific and have greatly reduced bird numbers. The proximity of remaining examples to settlements means that weeds are abundant and diverse, although the dense structure of intact examples means they can be highly resistant to weed invasion (Sullivan et al. 2005). However, their fragmented and regenerating state makes them more vulnerable to weeds.

WF6: Totara–broadleaved forest

IUCN 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, though soil fertility is generally low for all. Soils range from very recent Holocene coastal sands to younger Pleistoscene sands with a higher (10–20%) clay content (Molloy 1998). All soils are freely drained, however more recent examples are excessively so and are vulnerable to periods of moisture deficit. Parent material is mapped for Northland in Molloy (1998:84) and Scofield (1970). This includes the rare ecosystem 'Stable sand dunes' (Williams et al. 2007).

Distribution: From North Cape to Kawhia, Coromandel, Matakana Island and Bay of Plenty Coast to East Cape[2].

Characteristic native biota: Very few examples of the original dune forest remain; most examples are serial and are dominated by kanuka scrub. This ecosystem description is therefore somewhat speculative, being pieced together from the few remaining examples in better condition (e.g. Tapu and Pretty Bush), supported by the opinions of others (e.g. Ogle 2004; Smale et al. 2006).

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 and parabolic) dunes, kanuka would have been the primary coloniser, forming a largely monotypic forest. It was then likely succeeded by totara and a wide variety of broadleaved trees, including titoki, mahoe, rewarewa and pohutukawa. As soils developed, more broadleaved trees would have progressively colonised, including karaka, kohekohe, tawa, puriri, hinau and, locally, narrow-leaved maire and taraire. On the driest and exposed dune-ridge crests, kanuka may have persisted in association with other drought-tolerant species (e.g. ngaio, red mapou, pohutukawa and totara).

Variant i.) kanuka on dunes;
Variant ii.) podocarp broadleaved forest on dunes

[2] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

Regional variants of dune forest would have had different species compositions. Large dune-lands (e.g. north Kaipara head), being older and with more diverse landforms, probably had a greater range of dune-forest communities when compared to simple coastal dune ridges (e.g. eastern Coromandel beaches).

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. south and north Kaipara). The free-draining soils periodically result in significant summer moisture deficits, making the ecosystem highly vulnerable to fire.

Threats: This ecosystem is now very rare and threatened, with approximately less than 1% remaining across its entire range. This is largely due to pre-European fires and the resulting soil erosion and dune mobility. Extant examples are predominantly small fragments dominated by kanuka and other serial vegetation (Smale 1994). 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).

WF8: Puriri forest

<u>IUCN Status:</u> 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.

Distribution: In predominantly frost-free, warm and sub-humid areas from Northland to northern Waikato, Bay of Plenty and Poverty Bay[3].

Three variants occur:

(i) on alluvial terraces with recent free-draining (often stony) soils (Wardle 1991:120);

(ii) on shallow hill-slopes with melanic granular soils (e.g. Papakauri soil) in three main areas: Pukekohe–Auckland, Whangarei and Kerikeri–Kaikohe (Conning 2001; mapped in Molloy 1998:84). Youngest serial examples occurring on more recent basaltic lava flows in the Auckland volcanic field are colloquially described as 'lava forests' (Lindsay et al. 2009).

(iii) on alluvial terraces on recent fluvial (silt) soils derived primarily from mudstones and siltstones, especially on the East Coast (e.g. Greys Bush near Gisborne) (Clarkson & Clarkson 1991), and central Northland. Free-draining soils are prone to periods of moisture deficit in summer.

Characteristic native biota: Broadleaved forest with abundant puriri, with the composition of variants determined primarily by landform and soil type.

(i) puriri with occasional totara, matai, kahikatea and titoki, locally with kowhai and taraire

(ii) puriri with occasional taraire, totara, matai, pukatea, rewarewa, karaka, kohekohe, tawa, titoki and northern rata, and abundant nikau

[3] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

(iii) puriri with occasional kahikatea, kohekohe and nikau

On free-draining soils, secondary successions are often dominated by podocarp trees, with totara often abundant, especially in Auckland and Northland.

Key processes and interactions: Remaining examples suggest that this forest type occurred on alluvial terraces with moderate to highly free-draining fertile soils that are now rarely, if ever, flooded; it was also found on recent basaltic areas. Puriri seedlings are shade-tolerant, so the species is capable of regenerating beneath existing tall forest. It is long-lived and may dominate over hundreds to thousands of years. On productive soils, this forest type would have supported a large population of birds, essential for pollination and seed dispersal for most species present (Southward et al. 2002).

Threats: This ecosystem occurs on highly fertile soils prone to periods of moisture deficit, and it was greatly reduced in extent by Pre-European fires and later land development for agriculture and horticulture. Remaining examples are small and highly fragmented, and suffer from edge effects, stock grazing and weed invasion. Animal pests, especially possums and rats, are also significant threats, depleting palatable species and vulnerable fauna, including pollinators and seed dispersers.

WF9: Kahikatea–pukatea forest

<u>IUCN Status:</u> Critically Endangered

This ecosystem is essentially a swamp forest occurring 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 on lake margins (e.g. Lake Ponui, southern Wairarapa)[4].

It was more common in the warm–humid zone though extended into mild–humid areas, e.g. Egmont National Park (Clarkson 1986). Requiring a high water-table, it was likely restricted to wetland margins in semi-arid zones (e.g. Rarangi). In humid to semi-humid areas (e.g. western Waikato, Taranaki to Horowhenua), it was more widespread and common, especially on alluvial river terraces with recent fluvial soils derived from mudstone/siltstone/sandstone (e.g. Hutiwai River, Taranaki). On the Mt Taranaki ring plain on gley soils (Clarkson 1986) and in the Foxton Ecological District (e.g. Round Bush) (Ravine 1991), it occurred on organic soils in the depressions between lahar mounds and older stable dunes respectively.

Characteristic native biota: This ecosystem is dominated by podocarp–broadleaved forest, with emergent trees or a canopy of kahikatea and pukatea, locally rimu; swamp maire occurs in areas with a high water-table (Johnson & Brooke 1989), and tawa, mahoe and, locally, titoki are on areas of drier ground (Smale 1984). Kiekie and supplejack are often abundant, creating a dense structure and sub-canopy. In Northland, tararie and kohekohe occur on drier ground (McKelvey & Nicholls

[4] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

1959). Characteristic forest-floor species include *Gahnia xanthocarpa*, *Astelia grandis*, parataniwha and Colenso's hard fern. Modified fragments have characteristically had kahikatea harvested from them and are often now dominated by a forest of pukatea, swamp maire, kiekie and supplejack.

Key processes and interactions: Primarily dependent on a high water-table and limited if any periods of moisture deficit, 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 periodically been seasonally significant resources for many species (e.g. tui and kereru).

Threats: This forest type has been greatly reduced in extent with land development for agriculture, and 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 first 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 ground covers (e.g. wandering willy and African clubmoss) readily invade.

WF10: Rimu–taraire–tawa forest

<u>IUCN Status:</u> Critically 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 1957). Topography 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 450 m, from the lower Waikato district northwards, throughout Northland and on Great Barrier Island. It is absent in the coastal fringe and also occurs where Kauri forest (WF11) and Kauri–podocarp–broadleaved forest (WF12) are absent (McKelvey & Nicholls 1957)[5].

Characteristic native biota: Three major variants of this forest type occur, of which two are minor in extent (McKelvey & Nicholls 1959). The most common and extensive variant is characterised by large emergent rimu and northern rata, with kahikatea in gullies emerging over a broadleaved canopy of abundant taraire, towai, kohekohe and tawa, occasional hinau, rewarewa and pukatea, and, locally, puriri, miro and karaka. In the sub-canopy, tree ferns, especially mamaku, and nikau are locally abundant. On ridges, rimu, miro, rewarewa and mangeao are dominant, while pukatea is most numerous in gullies.

At higher altitude in humid locations and on poor-draining soils on hill-crests, this variant merges into another in which taraire, towai, swamp maire and tawari are often co-dominant, with raukawa

[5] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

and makamaka in the understory. A third variant occurs from north of Warkworth (Omaha Forest) south to the Hunua Range in the '*Weinmannia* gap', where both towai and kamahi are absent. In this variant, taraire is less abundant, while kohekohe, rewarewa, puriri, tawa and hinau are comparatively more common (Barton 1972).

Key processes and interactions: The most important factor influencing the composition this forest is the variable landforms it occupies. Native birds, especially kereru and tui, 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 shallow slopes was cleared for agriculture, and it is now largely restricted to more extensive forests on steep lands. Many remaining areas have been logged for podocarps, especially

rimu and kahikatea (Nicholls 1976). Animal pests are significant threats, with possums, goats and rats especially causing the decline of palatable flora and vulnerable fauna; possums and goats in combination have the potential to cause mortality and regeneration failure of palatable canopy and sub-canopy species (Payton 2000). Closed-canopy intact examples are highly resistant to weed invasion, though shade-tolerant ground covers (e.g. wandering Willy, African clubmoss and ginger) and trees and shrubs (e.g. monkey apple and bangalow palm) readily invade.

WF11: Kauri forest

<u>IUCN Status:</u> Critically Endangered

This iconic northern forest occurs in predominantly warm and sub-humid to 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 podozols 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 community dominated by manuka, tangle fern and sedges prevails; this is colloquially known as gumland (Meurk 1995; Clarkson et al. 2011).

Distribution: Northland, Auckland and Coromandel, now largely restricted to western Auckland, Northland hill country (e.g. Warawara and Waipoua forests), and small patches within the Waitakere and Coromandel ranges[6].

Characteristic native biota: Characterised by 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 totara, totara, tanekaha and, locally, Kirk's pine) and broadleaved trees (rata, tawa, taraire, hinau, rewarewa, kohekohe and

[6] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

towai). Regional variation occurs, for example taraire and towai are absent from the Waitakere Ranges. Characteristic sub-canopy species include *Dracophyllum latifolium*, kiekie, *Gahnia* spp. and *Astelia trinervia* (McKelvey & Nicholls 1959; Nicholls 1976; Ecroyd 1982).

Variant i) mature kauri forest
Variant ii) regenerating kauri "ricker" stands

Regenerating kauri forests are present throughout Northland, Auckland and Coromandel, generally replacing manuka and kanuka scrub on land that was previously burnt. These forests tend to have a high stocking of young kauri, often in association with tanekaha, occasional totara, rimu, rewarewa and towai. The ground layer is generally sparse owing to the density of the canopy trees.

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 Maori 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 animal pests, though pests can cause the decline of associated palatable flora, particularly the broadleaved component. Closed-canopy mature kauri forests are generally highly resistant to weed invasion. In some forests, kauri recently started suffering from *Phytophthora*- (taxon Agathis (PTA); Bellgard 2012) induced dieback.

WF12: Kauri–podocarp–broadleaved forest
IUCN Status: Critically Endangered

This diverse forest ecosystem is commonly derived from logged kauri forest, occurring in warm and sub-humid to humid areas with rainfall 1000–2500 mm. 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 350 m and up to 500–600m on the Coromandel Pennisula, Great Barrier and Little Barrier islands[7].

[7] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

Characteristic native biota: 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, totara, think-barked totara, miro and tanekaha more common on ridges, while kahikatea is more common in gullies and on alluvial terraces. Broadleaved trees are often dominant in gullies, including taraire, tawa, towai, kohekohe, puriri, northern rata, pukatea and rewarewa. Altitude variants occur, with taraire and kohekohe locally more abundant at lower altitude, while tawa and towai are more abundant at higher altitudes (McKelvey & Nicholls 1959; Nicholls 1976; Esler 1983).

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 podocarp trees (Wardle 1991). Native birds, particularly kereru and tui, are important for the pollination and seed dispersal of a wide range of canopy and sub-canopy species.

Threats: Significant human-induced modification from both Maori 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). Animal pests are significant threats, with possums, goats and rats especially causing the decline of palatable flora and vulnerable fauna. 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. wandering Willy, African clubmoss and ginger) and trees and shrubs (e.g. monkey apple and palms) readily invade. In some forests, kauri has recently started suffering from *Phytophthora-* (taxon Agathis (PTA); Bellgard 2012) induced dieback.

WF 13: Kauri–podocarp–broadleaved–beech forest

IUCN Status: Endangered

This forest type occurs in warm and sub-humid areas, generally below 600 m, 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 Range it is more common on southern-facing slopes (Barton 1972).

Distribution: Occurs predominantly in eastern areas south of Auckland, from the Hunua Range to Hapuakohe Ecological District in the Waikato. 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 600 m. 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)[8].

Characteristic native biota: Hard beech, occasional tanekaha, thin-barked totara, totara and kauri are generally confined to ridges; in gullies and on shallow hill-slopes, rimu, miro, tawa, hinau,

[8] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

northern rata, rewarewa, kamahi or towai and, locally, kohekohe, narrow-leaved maire and tawari occur (Nicholls 1976; Wardle 1984). In the Kaimai Range, in the southeastern limit of this forest type, kauri, hard beech and silver beech occur together at 600 m (Ecroyd 1982).

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 tanekaha. Shallow hill-slopes and gullies with soils of higher fertility and greater moisture availability 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 now difficult to determine because much of the suitable land on the eastern side of Northland, Auckland and the Coromandel Peninsula is now deforested, which mostly occurred prior to 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 once 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, though are largely secondary and modified by fire and logging. The greatest threat posed to the structure and composition is from animal pests, such as goats, possums and rats, causing the decline of palatable flora and vulnerable fauna (Payton 2000).

Closed-canopy intact examples are highly resistant to weed invasion, though shade-tolerant ground-covers (e.g. wandering Willy, African clubmoss and ginger) and trees and shrubs (e.g. monkey apple and palms) readily invade. In some forests, kauri has recently started suffering from *Phytophthora*- (taxon Agathis (PTA); Bellgard 2012) induced dieback.

WF 14: Tawa–kohekohe–mangeao broadleaved–podocarp forest

<u>IUCN Status:</u> 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 soils 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 Hunua and Coromandel ranges; in Northland it occurs on ranges above taraire's altitudinal limit, from 450 m to 550 m. From the Hunua Ranges into the Waikato and Bay of Plenty regions, it is the dominant forest type, often occurring inland from Pohutukawa–puriri– karaka broadleaved forest (WF9), on shallow to steep hill-slopes and gullies 150–550 m a.s.l. 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[9].

Characteristic native biota: Tawa and kohekohe are the most abundant canopy species. There are several regional variants with many co-occurring trees. Rimu, northern rata, miro and kahikatea are the most common emergent trees, while hinau, rewarewa and pukatea are often present in the canopy, locally with mangeao. Kamahi or towai, puriri and nikau also occur locally at lower altitudes. Towai and mangeao are locally absent or rare in some districts, while totara is more common (e.g. Auckland and East Cape) (McKelvey & Nicholls 1957; Nicholls 1976).

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 podocarp trees, such as rimu and kahikatea, often required periodic major disturbance events, such as cyclones. Native birds, especially kereru and tui, 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 land development for agriculture (Nicholls 1976). Animal pests are significant threats, with possums, goats and rats especially causing the decline of palatable flora (e.g. kohekohe and northern rata) and vulnerable fauna (e.g. kokako) (Payton 2000). 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. wandering Willy, African clubmoss and ginger) and trees and shrubs (e.g. privet and bangalow palm) readily invade (Wiser & Allen 2006).

[9] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

MF2: Kahikatea forest

IUCN Status: Critically Endangered

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 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)[10].

Characteristic native biota: It is characterised by abundant kahikatea, capable of forming a very tall, near-monotypic canopy. Along streams and rivers where soils are better drained, matai is present and can be locally co-dominant with kahikatea. Sub-canopy species include ribbonwood, *Hoheria* spp., kowhai, titoki, pokaka, mahoe, kaikomako, lemonwood and divaricating shrubs. Local variation occurs with the presence or absence of sub-canopy species, especially ribbonwood, hoheria and titoki. Pokaka is more abundant in areas with greater impeded drainage and frequent frosts, and in southern areas. In northern areas, pukatea is present (e.g. Manganui River) (Holland 2011), though in areas with the least frost severity. Several species of divaricating shrubs are characteristic, including turepo, small-leaved mahoe, *Coprosma pedicellata* and *Pittosporum obcordatum*. This ecosystem often inter-grades to either non-forest wetland or, on better-drained soils, alluvial forest types containing abundant totara, matai and, locally, titoki; and in northern North Island, puriri (units WF2 and WF8).

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

Threats: Much of this ecosystem type survived pre-European fires, even in eastern semi-arid areas (Meurk 2008); 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 occurred on flat land that was highly productive once it was 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 (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

[10] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

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 exotic) normally occurring in drier forest types (e.g. Gordon Park) (C.C.Ogle pers.com.). Despite being long recognised as a highly under-represented ecosystem type, many examples remain legally unprotected and grazed by stock.

MF 4: Tawa–*Weinmannia*–podocarp forest

<u>IUCN Status:</u> Least Concern

This common forest type is largely found in mild and sub-humid and humid regions of New Zealand where tawa and kamahi are both abundant. It occurs on a wide range of moderately fertile hill-slopes, which often are steep and erosion-prone. Northwards from Waikato to Bay of Plenty, it grades up-slope from Tawa–kohekohe–mangeao broadleaved–podocarp forest (WF14).

Distribution: A common forest type across the North Island and upper South Island, from Northland to the Marlborough Sounds, with at least four regional variants. In Northland, Hunua and Coromandel ranges, it occurs locally above 450 m on steep hill-slopes. It is particularly common on inland hill-slopes and ranges up to 600 m in the Waikato, Bay of Plenty, King Country, northern and southern Urewera and western Raukumara ranges. From the central to southern North Island, it occurs from Mt Taranaki, inland Wanganui and the western margin of the Tararua Range. In the east, it is only found at higher altitude in humid locations, particularly in the Tiniroto Ecological District and Tararua District. Small areas occur in the Marlborough Sounds[11].

Characteristic native biota: There are at least four variants of this podocarp–broadleaved forest with abundant tawa and *Weinmannia* (kamahi or towai):

(i) Northland—with scattered emergent rimu, northern rata and miro, abundant towai occasional tawa, tawari, hinau, rewarewa and, locally, pukatea and hutu;

(ii) Waikato/Bay of Plenty—occasional emergent rimu, miro, kahikatea, matai, totara and northern rata, abundant tawa and kamahi, occasional mangeao, hinau, rewarewa and, locally, pukatea

(iii) Central, eastern and southern areas—emergent rimu, miro, kahikatea, matai, totara and northern rata, abundant tawa, kamahi, hinau, rewarewa and pukatea, locally, tawari in north of range on non-volcanic soils;

(iv) Taranaki—scattered emergent rimu, miro, kahikatea and northern rata, abundant tawa, pukatea and mahoe, and, locally, kamahi and hinau (McKelvey & Nicholls 1959; Nicholls 1976).

Key processes and interactions: The major factors that influence the composition and structure of this forest type are the ridge–gully landforms it commonly occupies and the associated variability in soil fertility and moisture. The resulting forest pattern is a mosaic. Ridges and steep hill-slopes with shallow soils are occupied by towai or kamahi, miro, hinau, rewarewa and mangeao. Shallow hill-slopes and gullies with deeper soils of higher fertility and greater moisture availability are occupied by tawa, rimu, kahikatea and pukatea. Throughout its range, rimu is the most common podocarp

[11] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

tree. Native birds, especially kereru and tui, 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 North Island, this forest type has been greatly reduced in extent by logging and land development for agriculture (Nicholls 1976). Animal pests are significant threats, with possums, goats and rats especially causing the decline of palatable flora (e.g. kohekohe and northern rata) and vulnerable fauna (e.g. kokako) (Payton 2000). Possums and goats in combination have the potential to cause localised canopy collapse, especially of the *Weinmania* and rata component, and regeneration failure of many species within this ecosystem (Payton 200). Closed-canopy intact examples are highly resistant to weed invasion, though shade-tolerant shrubs (e.g. privet) readily invade (Wiser & Allen 2006).

MF22: Towai–rata–montane podocarp forest

IUCN Status: Least Concern

This higher-altitude forest ecosystem is limited in extent. It is colloquially known as 'cloud forest'.

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 on Great Barrier Island. These summits experience high rainfall, long periods of cloud cover, occasional snowfall and frequent high to gale-force winds, often from subtropical cyclones from the northeast (Ecroyd 1982). Owing to the age of landforms (and soils), high rainfall, and vegetation that forms acidic humus, soils are strongly leached, being dense volcanic clays (Molloy 1998)[12].

On Little Barrier Island, this ecosystem includes the rare ecosystem 'Sea-bird burrowed soil' (Williams et al. 2007).

Characteristic native biota: 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, Kirk's pine, toatoa and, locally, Hall's totara, tawari, towai, southern and Parkinson's rata, and quintinia. 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, tawari, quintinia and southern rata dominate, with occasional towai, Hall's totara, toatoa, broadleaf, mountain five-finger, *Dracophyllum* spp. and *Acheria racemosa*. Dwarfed kauri and miro are found sparsely among this (Hamilton 1961).

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 pahautea) (McEwen 1987). As a result, it is somewhat

[12] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

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. Several examples (e.g. Little Barrier and Great Barrier islands) have had fewer introduced pressures, some of which have been recently eradicated (e.g. cats and rats on Little Barrier and goats on Great Barrier), and their 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. Hall's totara and rata) (McCraith 2003). Animal pests, especially rats, have reduced the number of common birds. Climate and inaccessibility mean there are few weeds present.

This ecosystem experiences few if any periods of moisture deficit. Perhaps the most significant potential threat is from drought brought about by 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).

Coastal saline ecosystems

SA1: Mangrove forest and scrub
<u>IUCN Status:</u> Least Concern

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

Locally, this ecosystem may contain the historically rare ecosystems 'Shell barrier beaches' and 'Estuaries' (Williams et al. 2007),

Distribution: North of 38°S latitude from Raglan and Ohiwa[13].

Characteristic native biota: This ecosystem has a wide range of non-vegetated and vegetated communities, including mudflat, herbfield, rushland, scrub and low forest (Johnson & Gerbeaux 2004). On mud flats, where tidal inundation lasts longest, sea-grass community occurs. This is succeeded by mangroves, then rushland dominated by sea rush, and followed by oioi, *Baumea juncea* and saltmarsh ribbonwood (Deng et al. 2004). Areas of herbfield may occur, with glasswort, arrow grass, sea primrose, half star and sea blite. Where it occurs, the historically rare ecosystem 'Shell barrier beaches' includes a scattered herbfield of glasswort, *Austrostipa stipoides*, knobby clubrush, sea rush, sea primrose and sea blite (Ward 1967).

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[13] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

Variant i) mangrove
Variant ii) saline rushland/sedgeland
Variant iii) saline (estuarine) herbfield
Variant iv) intertidal flats (incl Zostera seagrass meadows)
Variant v) shell barrier beaches

Key processes and interactions: This ecosystem contains up to five distinct communities, largely distinguished by the duration of tidal inundation, elevation and salinity (Deng et.al 2004; Ward 1967), which is affected by fresh-water dilution. 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 habitat for a wide range of non-migratory and migratory wading birds, and is a nursery for species of fish (Turner & Schwarz 2006).

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 their catchments. Increased sedimentation rates have resulted in a decline of eelgrass and a subsequent increase in mangrove communities. Human pollution and reclamation are also threats where this ecosystem co-occurs with towns, cities and farmland, though the latter is now limited. 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 tolerant grasses (e.g. *Spartina* spp., saltwater paspalum and sea couch) can over-top and displace indigenous salt-marsh vegetation and wading-bird habitat (Partridge 1987; Shaw & Allen 2003).

SA4: Shore bindweed–knobby clubrush gravelfield/stonefield

<u>IUCN Status:</u> Critically Endangered

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

Gravel and boulder beaches occur 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).

At the shore, coastal processes sort grain size so that smaller grains are deposited further up the beach (Morton 2004). Over time this can create a beach ridge or a series of ridges, or a plain of pebbles to cobbles. Soils are initially 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 vegetation cover, soil forms with accumulating organic matter and windblown sediments. Occurring in close proximity to the coast, 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. More local in the North Island, it occurs in Wellington, Hawke's Bay, Taranaki and Coromandel–Firth of Thames. There are small examples on the Chatham Islands[14].

Characteristic native biota: A process of natural succession occurs on prograding gravel and boulder-beach coastlines, with youngest areas occurring closest to the coast having stonefield/gravelfield communities and older areas further inland grading into shrubland and treeland. There are at least four regional community variants, 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*, *Muehlenbeckia* and, locally, *Melicytus*, *Pimelea* and *Ozothamnus* spp., and harakeke; further inland, on older beach ridges, treeland includes, locally, ngaio, taupata, akeake, karo, kowhai, tanekaha and pohutukawa.

On the Chatham Islands, it is dominated by local endemics, including *Myosotidium hortensium* and *Embergeria grandifolia*.

A wide range of reptile fauna occurs within this ecosystem, including skinks and geckos; it locally provides nesting habitat for seabirds.

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 likely provided nesting habitat for a wide range of sea birds.

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, though 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, vehicle damage, land development for housing and, locally, viticulture. Weeds are particularly threatening, and Wiser (et al. 2010) identified that up to 50% of the flora occurring is exotic 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.

SA5: Herbfield (coastal turf)

<u>IUCN Status:</u> Not Evaluated

Herbfield, commonly known as coastal turf, occurs where coastal winds are sufficiently persistent and intense, delivering salt spray that prevents the establishment of taller vegetation; plants seldom

[14] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

grows to more than 50 mm tall. 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 Chatham Islands (Rogers 1999; Rogers & Wiser 2010). There are scattered examples elsewhere (e.g. Great Barrier Island) (Wright and Cameron 1985)[15].

Characteristic native biota: 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 minima*, *Isolepis cernua, Centella uniflora*, *Colobanthus muelleri*, *Hydrocotyle novae-zeelandiae,* and species of *Leptinella*, *Crassula*, *Ranunculus*, *Myosotis*, *Epilobium*, *Mazus* and *Nertera*. Broadly, there are four main regional variants (Taranaki–Wairarapa, northwest Nelson–north Westland, south Westland and Fiordland–Otago).

Key processes and interactions: Coastal turf is a very geographically restricted but highly distinctive ecosystem, primarily a result of frequent high winds laden with salt spray. In pre-human times, coastal turfs would have been used by a wide range of avian herbivores, as well as being resting and haul-out sites for marine sea birds and mammals. The presence of these fauna may have helped to develop and enhance areas of coastal turf through grazing, physical disturbance and increased nutrients from faeces (Rogers & Wiser 2010).

Threats: Most coastal turfs occur on private land, and their conservation values are poorly understood. 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, will be detrimental. Weeds are a significant long-term threat, especially from salt-tolerant herbaceous species such as buck's horn plantain, cape daisy and some exotic grasses.

SA7: Iceplant–glasswort herbfield/loamfield

<u>IUCN Status:</u> Critically Endangered

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

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

[15] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

Distribution: Formerly widespread on suitable coastal sites throughout mainland New Zealand from Northland to Otago, associated primarily with burrowing sea-bird colonies and abundant surface-nesting sea birds in exposed locations. It is now largely restricted to predator-free offshore islands[16].

Characteristic native biota: A mosaic of herbfield, including glasswort, iceplant, pigweed, shore groundsel, sea primrose, New Zealand celery and *Lepidium* spp.; locally, *Poa* spp. with scattered scrub–vineland of taupata, harakeke, ngaio, shrubby melicytus, *Hebe* spp. and *Muehlenbeckia complexa* interspersed with bare ground, bird burrows and guano deposits.

This ecosystem has abundant reptile fauna, including tuatara, geckos and skinks.

Key processes and interactions: In the absence of abundant burrowing sea birds, areas where this ecosystem occurs would likely be dominated by coastal forest trees or scrub. Large numbers of sea birds cause vegetation disturbance, arrested succession, soil instability, increased fertility and ecosystem productivity (Towns et al. 2009). The result is a mosaic of communities, including bare ground with bird burrows, guano deposits and vegetated areas dominated by early successional, predominantly herbaceous species and scattered, disturbance-tolerant shrubs and vines. These communities support greater numbers of invertebrates (Towns et al. 2009), which in turn support the abundant reptile fauna these ecosystems contain.

Threats: The most significant threat is from introduced predators, especially rats, which have caused the local extinction or heavy suppression of sea-bird populations (Jones et al. 2008). As a consequence, this distinctive fauna-derived ecosystem has become locally extinct from mainland New Zealand and many off-shore islands. Recent eradication of rats from some offshore islands will likely allow restoration of some examples. Declining sea-bird populations caused by fishing mortality and plastic consumption are also other threats.

These ecosystems are also highly vulnerable to invasion by a large number of nitrophilous, predominantly herbaceous weed species that occur in New Zealand, .

Wetland ecosystems

WL1: Manuka–mingimingi–*Machaerina* scrub/sedgeland (gumland)

IUCN Status: Critically Endangered

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: 92–94) have formed over thousands of years in humid areas with low-nutrient parent material and acid kauri leaf litter, which has leached base elements below the rooting zone, creating a podzol. As a result, drainage is strongly impeded and these soils are saturated for months, though Te Kopuru soils can be seasonally dry.

[16] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

Gumland vegetation likely expanded in extent as a result of pre-European fires (Esler & Rumball 1975; Clarkson et al. 2011). Periodic natural fires may have also arrested the succession to taller scrub and maintained the characteristic low-stature vegetation.

This ecosystem includes the rare ecosystem 'Gumlands' (Williams et al. 2007).

Distribution: Occurs in Northland, Auckland and Coromandel regions north of 37°S, congruent with the distribution of kauri[17].

Characteristic native biota: 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, vegetation patterns of two types occur, with manuka and mingimingi on better-drained sites and tangle fern in the poorest-draining and higher-nutrient sites. Other co-occurring plants in these communities include species of *Baumea*, *Schoenus*, *Gahnia*, *Tetraria* and *Lepidosperma* sedges, and, locally, *Epacris* and *Dracophyllum*. Gumlands support a wide range of threatened plants, many of which are ground orchids (de Lange et al. 2009).

Variant i.) true gumland heath (per Clarkson et al., 2011), e.g. Waikumete Cemetary
Variant ii.) manuka on poorly drained substrates, but without all key characteristics of true gumland heath which include Podzol and Ultic soils (strongly leached and acidic), seasonal waterlogging, low nutrients and occasional fires.

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. manuka that regenerates on bare surfaces) (Clarkson 1997). Gumland vegetation has a low number of endemic species (47%) compared to the New Zealand average (82%), and many species (44%) are shared with Australia (Clarkson et al. 2011).

Threats: Gumlands have been greatly reduced in extent since the 1840s, when they occupied approximately 300,000 hectares, though 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 and water-logged conditions (e.g. Spanish heath, gorse, pines and *Hakea* spp.). The dominant hard-leaved, nutrient-poor vegetation means that animal pests are a 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* spp.).

[17] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

WL2: Manuka–wirerush–restiad rushland

<u>IUCN Status:</u> Critically Endangered

This ecosystem occurs in inland wetlands in northern, warm and sub-humid areas that are 1500–7000 years old (Clarkson et al. 2004). Their soils are organic and their 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 in Northland and Waikato lowland plains (e.g. Motutangi Swamp, Northland and Whangamarino, Waikato)[18].

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

Key processes and interactions: Though these wetlands are mesotrophic, they are on the pathway to being oligotrophic bogs with time, accumulation of peat, a reduction in nutrient availability and colonisation by *Sporadanthus ferrugineus* (Clarkson et al. 2004). They are highly flammable and were known to burn in pre-human times on a one-to-several-century cycle (Clarkson 1997). They often integrate 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 Maori and Europeans, which may have on occasion resulted in their organic soils combusting. 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 (e.g. blueberries), which have recently started to invade.

WL3: Bamboo rush, wirerush restiad rushland

<u>IUCN Status:</u> Collapsed

This ecosystem occupies ombrotropic 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).

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[18] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

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)[19].

Characteristic native biota: 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 wire rush, with occasional scrub of manuka, *Dracophyllum lessonianum* and *Epacris sinclairii*, and, locally, *Lycopodiella lateralis*, *Baumea teretifolia*, *Schoenus brevifolius* and tangle fern. May include small embedded pools with sphagnum, *Utricularia* and *Drosera* spp. (Campbell 1964; Clarkson 1997; de Lange et al. 1999).

Key processes and interactions: These 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 ombrotropic (Clarkson et al. 2004). Prior to human arrival, natural fires occurred on one-to-several-century cycle (Clarkson 1997). These fires were likely important disturbance processes that maintained early successional species (e.g. *Azybas carsei*) (Norton & de Lange 2003)

Threats: This ecosystem once occupied >100,000 hectares but was eliminated from 95% 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, Kopouatai and Moanatuatua bogs, of which only Kopouatai 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 associate species), but excessive burning could also eliminate it (NZCPN *Sporadanthus ferrugineus* factsheet). This ecosystem is highly resilient to weed invasion, though acid-loving ericaceous species (e.g. blueberries) have recently invaded some areas.

WL10: Oioi restiad rushland/reedland

<u>IUCN Status:</u> Critically Endangered

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

[19] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

Distribution: Riverine/lacustine wetlands in North, South and Chatham islands, occurring in fresh-water areas of estuaries, coastal stream margins and in some inland areas adjacent to lakes (e.g. central North Island and Southland)[20].

Characteristic native biota: Abundant oioi, locally with large *Machaerina* and *Bolboschoenus* spp., kuta and lake clubrush, often with scattered raupo and harakeke. Often grades up-slope into wetland scrub on margins (Deng et al. 2004).

Key processes and interactions: This ecosystem is primarily coastal and 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 saltmarsh 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 exotic species.

WL11: *Machaerina* sedgeland

<u>IUCN Status:</u> Critically Endangered

Machaerina sedgeland occupies mesotrophic wetlands in shallow depressions, and sheltered lake and lagoon margins 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. Kakapo Mire). Examples on the margins of mesotrophic lakes include Lake Waikareiti and Lake Rotopounamu[21].

Characteristic native biota: This ecosystem is dominated by sedgeland–rushland of a wide range of regional variants and includes species of *Machaerina*, *Lepidosperma*, spiked sewdge rush 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. rubignosa* 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 and lake clubrush are more abundant on raw soils on lake margins (Kapa and Clarkson 2009). Locally includes oioi, tangle fern and *Gahnia* spp., and often grades up-slope into wirerush, tangle fern or manuka, *Coprosma* scrub fens.

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

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[20] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

[21] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

highly productive and accumulate large amounts of dry matter that forms 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 owing to lake eutrophication and invasion by raupo and competitive weeds (e.g. floating sweetgrass).

WL15: Herbfield (lakeshore turf)

IUCN Status: Data Deficient

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 rare ecosystem 'Lake margins' (Williams et al. 2007).

Distribution: Lacustrine wetlands associated with coastal (e.g. Lake Wairarapa and Lake Forsyth) and inland lakes (e.g. Lake Manapouri, Lake Te Anau, Lake Waikaremona and Lake Taupo) in North, South and Chatham islands[22].

Characteristic native biota: A relatively species-diverse ecosystem type consisting of a tight herbfield to low sedgeland, with few species exceeding 20 mm in height (Johnson 1972). There are broadly two variants: (i) coastal and (ii) inland; species are often common to both variants.

Coastal lakes are often brackish and commonly include *Selliera radicans*, *Isolepis* spp., *Limosella* and *Lilaeopsis,* and can grade into saltmarsh with increasing salinity. Inland variant commonly includes *Glossistigma elatinoides*, species of *Lilaeopsis*, *Carex*, *Eleocharis*, *Lobelia*, *Centrolepis*, *Hydrocotyle*, *Myriophyllum*, *Plantago*, *Ranunculus*, *Crassula* and *Viola,* and other herbaceous species.

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. *Myriophyllum* and *Potamogeton* spp.) 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 suffer from moisture deficit and die off. Most species only flower and produce seed while exposed.

[22] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

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. *Veronica serpylliflora* (Johnson & Brooke 1989). Lake eutrophication and koi carp are also threats because they both reduce water clarity, limiting the light that reaches this ecosystem when it is submerged. Lake eutrophication can also further exacerbate the growth of exotic weeds.

WL18: Flaxland

<u>IUCN Status:</u> Critically Endangered

Flaxlands are swamps that occur on young landforms (Bagnall & Ogle 1981) that regularly flood or receive surface flow from surrounding land. They are most common in depressions 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 northwest Nelson (e.g. Mangarakau) to South Westland. Also present inland in cool districts, e.g. Waiouru and Canterbury (e.g. Lake Coleridge)[23].

Characteristic native biota: 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. pukio), *Machaerina*, *Ranunculus* and *Epilobium*, and occasional wetland scrub and scattered treeland of cabbage tree, *Coprosma* spp., manuka, and, locally, weeping matipo and *Olearia virgata* (Johnson & Brooke 1998). In areas with a higher water-table, they often intergrade down-slope into areas dominated by pukio and raupo. Margins of flaxland often grade into wetland carr (fen overgrown with trees), with emergent cabbage trees, manuka and scattered kahikatea.

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 will develop into mesotrophic fens as nutrient inputs decline and they accumulate organic matter. Some flaxlands will succeed, with time, into cabbage-tree carr and eventually swamp forest (Esler 1978; Sykes et al. 1991).

[23] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

Threats: Flaxlands have been greatly reduced in extent for agricultural 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), there are only small fragments remaining (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. However, extensive flaxlands remain in high condition on the West Coast of the South Island. Flaxlands are colonised by a wide range of weeds, many of which are transformer species (e.g. willows) capable of displacing a large number of species.

WL 19: Raupo reedland

<u>IUCN Status:</u> Critically Endangered

Raupo reedlands occur on the margins of lakes, lagoons, ponds and river oxbows, and in flooded valleys. They are generally marshes with mineral soils and a wide 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. Raupo 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[24].

Characteristic native biota: This ecosystem type is dominanted by abundant raupo, locally with species of purua grass, lake clubrush, jointed twig rush, toetoe, pukio and harakeke. In areas of shallow water, it includes floating or rafted aquatics, such as water milfoils, buttercups, willowherbs, pondweed, clubrush, azolla, duckweed and spiked sedges (e.g. kuta). Raupo reedland often grades up-slope into Flaxland (WL18) and/or *Coprosma*-dominated scrub, locally with manuka and scattered kahikatea on wetland margins.

Key processes and interactions: Raupo 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 3 m in height. From late autumn, this foliage dies down and the plant rests over winter as subterranean rhizomes. Raupo 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 water fowl, and it is frequently a primary coloniser around constructed dams and farm ponds, though these examples tend to be floristically poor.

Threats: Forest clearance caused by pre-European settlers increased flooding, sedimentation and eutrophication of formerly mesotrophic fen wetlands, resulting in an expansion in extent of raupo 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 raupo, though it is likely also detrimental to

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[24] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

many subordinate species in this ecosystem (Cooke et al. 1990). Confounding this increase in vigour and abundance is that the area of raupo reedlands has likely reduced with wetland drainage (e.g. western Lake Wairarapa). Declining condition has also occurred where stock grazing has caused considerable damage.

Raupo 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 that are capable of invading and dominating include Manchurian rice grass, reed canary grass, floating sweetgrass and alligator weed, however the former two have very restricted distributions within New Zealand. Raupo reedlands often contain numerous subordinate invasive weeds, such as water purslane, water speedwell, water celery and beggars' ticks.

WL 20: *Coprosma–Olearia* scrub

<u>IUCN Status:</u> Critically Endangered

Coprosma, *Olearia* scrub swamps occur on moderate- to high-fertility soils that are seasonally wet. They also frequently occur as narrow ecotone bands between forest and low-stature wetland types.

Distribution: Palustrine/riverine/lacustrine wetlands throughout New Zealand, from Northland to Stewart Island[25].

Characteristic native biota: This ecosystem is dominated by a low-statured, often dense canopy of one or more species of *Coprosma* or *Olearia*. *Coprosma propinqua* nationally is the most widespread and is often dominant; it commonly occurs with swamp coprosma (Johnson & Brooke 1989). Twiggy tree daisy can be locally dominant, especially in the central to southern North Island (Lake & Whaley 1995; Beadel et al. 2004). Other scrub or shrub species include manuka, Taylor's coprosma, *C. rugosa*, and species of hebe and New Zealand broom, though these are always subordinate. The understory includes a wide variety of carex sedges and, locally, kiokio and swamp kiokio. Scrub or shrub swamps may locally include scattered harakeke, toetoe, *Astelia* spp. and cabbage trees.

Key processes and interactions: Scrub swamps occur on intermittently wet soils and often grade up-slope from Flaxlands (WL18). Some examples are likely successional, overtopping flaxlands and then being replaced by wetland forest species, such as kahikatea.

Threats: Unlike most monocotyledonous wetland vegetation, such as flax, raupo and pukio, woody wetland vegetation generally dies when burnt. Maori and European fires undoubtedly greatly reduced the number and extent of scrub swamps. Remaining examples tend to be restricted to humid regions with limited human history, such as the West Coast (McGlone 2009), or are small in size. As they occur on soils that are often seasonally dry, they are relatively easy to graze, drain and develop into pasture. Scrub swamps are vulnerable to invasion by a range of tree and climbing weeds, such as grey willow, alder, sycamore, Japanese honeysuckle, and grasses, herbs and ferns, such as royal fern.

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[25] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

Dune ecosystems

DN2: Spinifex–pingao grassland/sedgeland

IUCN Status: Endangered

Active dunelands occur wherever there is a supply of coastal sands in association with wind action, resulting in the lifting, transport and deposition of sand grains. They include a wide range of forms, from single vegetated ridges at the rear of a beach to dune systems that extend inland for many kilometres. Dunes also experience periodic drought, high surface temperature, salt winds, sand-blasting and low nutrient availability (Hesp 2000). They may be mobile as a result of disturbance events, or when sediment supply exceeds the capacity of plants to contain it (Muckersie & Shepherd 1995). Mobile dunes move inland with the prevailing wind, smothering vegetation and facilitating a new dune succession.

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

Distribution: This ecosystem occurs within the warm–mild coastal dunelands from Northland to Farewell Spit. Historically, it was scattered further south to Buller River (West Coast) and to the Waimakariri River in the east, to the southern limits of spinifex[26].

Characteristic native biota: 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, *Atriplex hollowayi* and *Carex pumila* may occur, though the former is now rare and restricted only to the Far North (de Lange et al. 2000). On an accreting shoreline, pioneer dune-building plants include spinifex and pingao, locally with sand tussock and shore bindweed and, further inland, sand coprosma, tauhinu, sand daphne and *Muehlenbeckia complexa*. With vegetation succession, active dunes become increasingly stable, supporting an open scattered dune scrub, fernland, and vineland of bracken, *Muehlenbeckia complexa*, toetoe, harakeke and cabbage trees. Locally, semi-stable dunes also include matagouri, manuka, kanuka, tutu and *Olearia solandri*.

Key Processes and Interactions: to come??

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, lupins, sand wattles). 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 invasive 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 impacts.

[26] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

DN5: Oioi–knobby clubrush sedgeland

<u>IUCN Status:</u> Not Evaluated

This ecosystem occupies dune plains or coastal plains (Esler 1969 & 1970), which are areas of flat land between dune ridges. 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 *Carex pumila*, 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 that are periodically submerged wetland communities separated by small sand ridges with drier communities. Dune plains have raw sandy soils that are free-draining. Flooding may occur at all times of the year following heavy rainfall (Singers 1997).

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

Distribution: North Island, largely in Northland (e.g. Aupouri, Poutu, South Kaipara) and Foxton Ecological District (South Taranaki to Paekakariki); South Island (e.g. Farewell Spit, Canterbury, Otago, Southland) and Stewart Island. Historically, they may have been present elsewhere (e.g. Matakana Island, Bay of Plenty) but are no longer present[27].

Characteristic native biota: Dune plains are initially colonised by sedgeland and herbfield of several local variants, with both dry and ephemerally wet communities. Dominant species include *Carex pumila*, species of *Gunnera*, *Selliera*, *Isolepis*, *Epilobium*, *Ranunculus*, *Leptinella*, *Lobelia*, *Colobanthus*, *Geranium* and *Hydrocotyle,* and, locally, *Lilaeopsis novae-zelandiae*, *Myriophyllum votschii*, *Triglochin striata*, *Limosella lineata* and other turf-forming species. These are then succeeded by taller plants, especially oioi, knobby clubrush, toetoe and, locally, *Cyperus ustulatus*. Locally, older successions include harakeke, *Coprosma propinqua* and manuka.

Dry deflation hollows or sandy mounds are colonised by drought-tolerant species, including knobby clubrush, *Lepidosperma australe*, silver tussock, jersey cudweed, *Raoulia* spp. and, locally, woollyheads.

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), succession of dune plains occurs, with flaxland–wetland scrub, cabbage tree carr and, eventually, swamp forest.

[27] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

Dune plains provide habitat for a wide range of birds, including dotterels, fernbird and, when dune slacks are full of water, stilts and dabbling ducks; however, many of these species have declined in number and are often no longer present.

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 exotic-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 widely used by off-road vehicles.

Cliff ecosystems

CL 1: Pohutukawa treeland/rockland

<u>IUCN Status:</u> Not Evaluated

The environmental factors that determine the composition and structure of this ecosystem are the steep erosion and drought-prone slopes, salt spray and physical impacts (windiness) of being adjacent to the sea. Plants found here are tolerant of high levels of salt on their leaves and in soils.

Distribution: Coastal cliffs, highly erosion-prone hill-slopes and colluvial slopes with pohutukawa occur in frost-free mainland and island areas from the Three Kings Islands to northern Taranaki in the west and to Poverty Bay in the east. This ecosystem is particularly abundant on many offshore islands, such as Poor Knights, Little Barrier and Great Barrier[28].

Characteristic native biota: This is a mosaic of treeland, shrubland, flaxland, herbfield and rock, with locally abundant pohutukawa and occasional houpara, taupata, karo, kawakawa, New Zealand broom, hebes, harakeke, rengarenga lily, coastal astelia, knobby clubrush and, locally, northern tussock. Halophytic herbs (e.g. New Zealand ice plant, pigweed, half star and shore celery) are often abundant on the shore. Colluvial slopes and toe slopes at the base of cliffs and small gullies often include stunted coastal trees, such as karaka, kohekohe, tawapou, wharangi and turepo. The ecosystem often includes small seeps with coastal wetland species such as slender clubrush. Northern offshore islands (e.g. Three Kings and Poor Knights) have additional endemic species, such as Poor Knights lily (Esler 1978; Baylis 1986; Clarkson 1990; Wardle 1991; Lindsay et al. 2009).

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. Cliffs additionally often experience significant periods of drought, especially if north-facing. Coastal cliffs host lichen,

[28] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

bryophyte, herb, grass, fern, shrub and small-tree species on the limited micro-habitats where soil forms or where their roots penetrate rock fractures.

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

Threats: Coastal cliffs are constantly being impacted by 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 and pines.

Possums are the most significant animal pest; they threaten the composition and structure, and have caused significant pohutukawa dieback around the northern coastline (Payton 2000). Predators have also greatly reduced the numbers of sea birds, which in pre-human times would have been abundant and would have locally increased fertility.

CL 6: Hebe–wharariki flaxland/rockland

<u>IUCN Status:</u> Not Evaluated

This ecosystem occurs on cliffs, rock outcrops, and highly erodible steep slopes and their down-slope debris 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 that 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 (Matemateaonga 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; Beadel 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 adjacent to incised rivers in areas with highly erodible parent materials (such as mudstone/siltstone/sandstone) in eastern North Island, Rangitikei and Wanganui districts. It is also associated with hard volcanic rocks throughout the central North Island and locally elsewhere[29].

Characteristic native biota: It occurs over a wide latitudinal and altitudinal range, with several regional variants, though regional compositional diversity is poorly known because of a lack of ecological descriptions. Vegetation is successional, and composition and structure are strongly related to slope steepness, rock hardness and age 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 limited vascular plants. With weathering and soil accumulation, short-statured herbs, grasses and

[29] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

wharariki colonise ledges and crevices. 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. Dominants species include wharariki, broad-leaved poa, species of hebe, snowberry, New Zealand daphne, tree daisy, kowhai and New Zealand broom, *Leucopogon*, neinei, broadleaf, manuka, tutu and, locally, rata lianes, ngaio, kanuka, snow tussock, perching lily, turutu and *Collospermum hastatum*. In inland and higher-altitude sites, cliff communities include sub-alpine species, such as *Hebe colensoi*, mountain daisies and New Zealand daphnes (Wardle 1991).

Rare local endemics occur in some locations, such as *Pimelea mimosa* and *Hebe saxicola* on base rich calcareous and volcanic parent materials (de Lange & Rolfe 2008; Burrows 2011).

Key processes and interactions: This ecosystem includes many species that occur in a wide variety of other habitats interspersed with specialists, restricted to rupestral habitats. Hard rock cliffs have fewer vascular plants, likely because they experience severe moisture deficits 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 kowhai, even on near-vertical surfaces.

Threats: Cliff habitats provide refugia from many threats, such as herbivorous pests, fires and land development. Often in intensively developed agricultural areas, cliff 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 that are frequently disturbed, weeds readily invade (Wiser & Allen 2006), and numerous species of grass, shrub, liane and tree weeds are significant threats (e.g. Mexican daisy, pampas, gorse, broom, buddleia, cotoneaster, old man's beard, ivy and wilding pines).

Geothermal ecosystems

GT 2: Geothermal-heated water and steam

IUCN Status: Least Concern

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 (from >100°C to <25°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 influences species composition.

Distribution: This hotwater ecosystem type predominantly occurs and is most extensive in the Taupo Volcanic Zone (Boothroyd 2009), though there are small examples in Northland (e.g. Ngawha) and the Auckland volcanic centres. Hot-water springs are also associated with tectonically active faults, generally close to the axial ranges, in central North and South Island from South Marlborough to South Canterbury (Stark et al. 1976)[30].

Characteristic native biota: Geothermal 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 (Cody 2007; Boothroyd 2009; Stark et al.1976). Over 200 different species of algae, including diatoms to cyanobacteria, are known to occur in thermal waters (Cassie-Cooper 1996). Commonly occurring invertebrates include mayflies, crane flies, midges and molluscs.

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

Key processes and interactions: Geothermal heated water ecosystems are extreme environments for life to inhabit, having high temperatures, dissolved minerals and often low acidity. The composition of this ecosystem is still being understood. 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 utilise 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 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 geothermal 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 utilised for heating, industrial and electricity purposes, and this use 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

[30] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

generally involves reinjection to maintain aquifer pressure, and this is helping to conserve surface features.

While terrestrial geothermal heated soils and ecosystems are threatened by invasive species such as weeds, far fewer invasive species occur in aquatic geothermal systems. 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 or crustacean populations is unknown.

Cave ecosystems

CV 1: Subterranean rockland/stonefield

<u>IUCN Status:</u> Least Concern

Most **c**aves 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, ground-water 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 eruption of the lava while it is still fluid (Hamilton-Smith & Finlayson 2003). Cave ecosystems have a saturated humidity and a constant temperature that is relative to the climate 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 the King Country to inland Taranaki, northwest Nelson and West Coast. Cave systems are most extensive in areas of high rainfall[31].

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

Characteristic native biota: Cave ecosystems are dominated by a range of detrivorous 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 (Crustaceae) (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, across isolated karst blocks.

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 the bodies or wastes of animals that enter the cave (Hunt & Millar 2001). Species may occupy both terrestrial and aquatic environments in the cave, likely because the terrestrial cave environment has a saturated humidity.

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[31] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

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).

Regenerating ecosystems

FI 1: Kanuka scrub

IUCN Status: Least Concern

Kanuka (*Kunzea ericoides*) is a species complex with several unnamed entities (Dawson & Lucas 2011). As a result of frequent fires, kanuka scrub occupies many sites that were formerly tall forest (Wardle 1991). Kanuka scrub is promoted by fire over many decades, even centuries, which prevents its replacement by tall forest species, such as beech and podocarp trees. Fires that occur too frequently remove kanuka seed sources and promote fast-growing, non-woody and fire-resistant species, such as grasses and bracken (Burrell 1965).

Distribution: Throughout New Zealand from North Cape to Otago. As a dominant kanuka 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 that experience summer soil-moisture deficits, such as north-facing hill-slopes and recent alluvial or sandy raw soils. Kanuka is highly competitive in semi-arid climates and sites that are too dry for manuka, predominating vegetation successions in Otago where rainfall is less than 650 mm (Burrows 1973), and similar sites in Canterbury, such as Rakaia Island (Meurk 2008). Kanuka is frost-tolerant, and its upper altitudinal limit is approximately 1000 m on the Volcanic Plateau (Rogers & Leathwick 1994)[32].

Characteristic native biota: Kanuka scrub occurs over a wide latitudinal and altitudinal range, and variable regional vegetation successions occur that are representative of local conditions and available seed sources. Kanuka may establish on bare surfaces following fire and also locally succeeds into gaps within sparse grasslands. Transitional communities often contain a wide variety of grassland and scrub species. Some associate species are almost ubiquitous throughout its range, such as soft mingimingi, prickly mingimingi, *Coprosma rhamnoides* and tauhinu (Wardle 1991; Allen et al. 1992; Ecroyd & Brockerhoff 2005; Sullivan et al. 2007). As stands age, kohuhu, mahoe, five-finger, lancewood, kowhai, karamu, putaputaweta and, locally, broadleaf are also common associates in most regions, except in the most edaphically dry sites. Kanuka scrub also provides ideal conditions for the regeneration of many tall forest trees, including beech (Wardle 1991, 2001), and

[32] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

podocarps such as totara, matai, tanekaha and alpine celery pine (Wilson 1994; Sullivan et al. 2007; Esler & Astridge 1974; Rogers & Leathwick 1994).

Key processes and interactions: Kanuka 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. Kanuka locally replaces Manuka–kanuka scrub (FI2) in sub-humid zones (Stephens et al. 2005). In pre-human times, kanuka 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, kanuka 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. Kanuka communities can be long-lived, remaining for 80–150 years, though some trees can survive up to 250 years, reaching 30 m in optimal sites (Burrows 1973; Dawson & Lucas 2011). On extreme edaphically dry sites (Burrell 1965) or sites with sufficiently high ungulate abundance to stall succession (Payton et al. 1984; Smale et al. 1996), kanuka may regenerate beneath itself.

Threats: Kanuka 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). Kanuka 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 kanuka 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). Kanuka 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.

FI 2: Manuka–kanuka scrub

IUCN Status: Least Concern

Manuka and kanuka 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, manuka occupies areas that are too wet, cold, exposed, infertile or unstable for tall forest (Burrows 1973), while kanuka occupies sites that are too 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. Manuka and kanuka have similar tolerance of frost (from -9°C to +/- 1°C) (Bannister 2007), although the upper altitudinal limit of kanuka is lower (at approximately 1000 m) on the Volcanic Plateau (Rogers & Leathwick 1994).

Distribution: 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[33].

Characteristic native biota: 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 mahoe, species of *Coprosma*, *Pittosporum* and *Pseudopanax*, locally kawakawa, red maupo 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, beech and broadleaved canopy trees establish early in the succession and ultimately replace kanuka in the canopy (Esler & Astridge 1974; Smale 1993a, 1993b). This pattern is mirrored in other regions, though species differ from region to region.

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). Manuka and kanuka establish concurrently following a disturbance event such as fire, and 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, kanuka replaces manuka 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 kanuka 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, in the Golden Bay region, kanuka stands 100 years old were predicted to be dominated by an equal abundance of kanuka and pole-sized canopy trees, such as various podocarps, silver beech, kamahi and northern rata (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), a pattern that represents use of the stands by small birds (e.g. silvereye and bellbird) and then large (e.g. kereru and tui) with time (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 Maori 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 seed-banks that

[33] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

readily germinate after fire and can out-compete manuka and kanuka during the initial colonisation phase. Older Manuka–kanuka scrub (FI2) 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.

Manuka and kanuka are both unpalatable to stock, ungulates and possums, and readily invade erosion-prone hill-slopes and low-producing pasture (Smale et al. 1997). While neither is directly impacted by these pests, they alter successional processes and prevent canopy species establishing. This leads to vegetation succession being dominated by unpalatable species, such as various podocarp trees, with fewer palatable broadleaved species (Bray et al. 1999) and, locally, multiple cohorts of kanuka (Payton et al. 1984).

FI 4: Broadleaved scrub/forest

<u>IUCN Status</u>: Least Concern

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

Distribution: Broadleaved scrub/forest is most abundant in sub-humid and humid regions from Northland to Stewart Is, although it is also locally present in semi-arid regions[34].

Characteristic native biota: 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 Manuka–kanuka scrub (FI2) 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 karamu, shining karamu and kanono), *Pseudopanax, Pittosporum,* tree daisy, hebe and hoheria, rangiora, tutu, putaputaweta, mahoe, red maupo and wineberry. Locally in gullies and in humid climates, kotukutuku, pate, kamahi and tree ferns (including mamaku, ponga and wheki-ponga) may be abundant. Southern rata is especially common on the West Coast (Newsome 1987; Wardle 1991).

In sub-humid and semi-arid regions in eastern New Zealand, species of kowhai, ribbonwood, kaikomako and, locally, cabbage trees and ngaio occur, and broadleaf in cool climates (Wardle 1991).

Key processes and interactions: Broadleaved scrub/forest is an advanced stage of forest succession, often replacing bracken (Wardle 1991; McGlone et al. 2005) or manuka (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

[34] For the current distribution in Auckland see "*Spatial extent of Auckland's indigenous terrestrial and freshwater ecosystems*" (2013).

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 mahoe, it is capable of supporting high herbivorous pest populations. Long-term pest pressure could deplete palatable species (Payton 2000), favouring succession towards non-palatable species, such as ponga, soft tree fern and podocarps (Wardle 1991).

Weeds are also locally significant threats, especially if it occurs 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 old man's beard, Japanese honeysuckle and banana passionfruit, or trees such as sycamore and privet (Wilson 1994, 2003; Williams 2011). In some circumstances where few tall trees remain in the landscape, regeneration to tall forest is likely being stalled as a result of limited seed availability (ref).

References

DRAFT

Glossary of plant names

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

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 and Rolfe 2010. New Zealand indigenous vascular plant checklist. New Zealand Plant Conservation Network.

Common Name	Scientific Name	Ecosystems
African clubmoss	*Sellaginella kraussiana*	WF9, WF12, WF14
*agapanthus	*Agapanthus praecox* subsp. *orientalis*	CL1
akeake	*Dodonaea viscosa*	SA4
*alder	*Alnus glutinosa*	WL20
*alligator weed	*Alternanthera philoxeroides*	WL19
arrow grass	*Triglochin palustris*	SA1, SA4, GT2
astelia	*Astelia* spp.	MF22, WL20
azolla	*Azolla filiculoides*	WL19
bamboo rush	*Sporadanthus ferrugineus*	WL1, WL3
*banana passionfruit	*Passiflora* spp.	FI4
*bangalow palm	*Archontophoenix cunninghamiana*	WF10, WF12, WF14
*beggars' ticks	*Bidens frondosa*	WL19
*blackberry	*Rubus fruticosus* agg.	WL2, FI2
bladderwort	*Utricularia* spp.	WL3
*blueberry	*Vaccinium corymbosum*	WL2, WL3
bog rush	*Schoenus pauciflorus*	
bracken	*Pteridium esculentum*	DN2
broadleaf	*Griselinia littoralis*	MF22, CL6, FI1, FI4
broad-leaved poa	*Poa anceps*	CL6
*broom	*Cytisus scoparius*	CL6, FI1, FI2, FI4
*buck's horn plantain	*Plantago coronopus*	SA5
*buddleia	*Buddleja davidii*	CL6
buggar grass	*Austrostipa stipoides*	SA1
buttercup	*Ranunculus* spp.	SA5, WL15, WL18, WL19, DN5
button daisy, cotula	*Leptinella* spp.	SA5, DN5
cabbage tree	*Cordyline australis*	WL18, WL20, DN2, FI4
cape daisy	*Arctotheca calendula*	SA5
centella	*Centella uniflora*	SA5
centrolepis	*Centrolepis* spp.	WL15
*Chilean rhubarb	*Gunnera tinctoria*	CL9
christella	*Christella dentata*	GT2
clubrush	*Isolepis* spp.	WL15, WL19, DN5, CL1
coastal astelia	*Astelia banksii*	CL1
coastal cutty grass	*Cyperus ustulatus*	DN5, GT2
coastal tree daisy	*Olearia solandri*	DN2
Colenso's hard fern	*Blechnum colensoi*	WF9
Colenso's hebe	*Hebe colensoi*	CL6
collospermum	*Collospermum hastatum*	CL6
coprosma	*Coprosma* spp.	SA4, WL11, WL18, CL9, FI2
*cordgrass	*Spartina* spp.	SA1
*cotoneaster	*Cotoneaster* spp.	CL6, FI2
*crack willow	*Salix fragilis*	WL15, WL18
crassula	*Crassula* spp.	SA5, WL15

cress, scurvy grass	*Lepidium* spp.	SA7
dracophyllum	*Dracophyllum* spp.	WL1
duckweed	*Lemna* spp.	WL19
eelgrass		
*evergreen buckthorn	*Rhamnus alaternus*	CL1
five-finger	*Pseudopanax arboreus*	FI1, FI4
*floating sweetgrass	*Glyceria maxima*	WL11, WL19
forget-me-not	*Myosotis* spp.	SA5
gahnia	*Gahnia* spp.	MF22, WL1, WL11
geranium	*Geranium* spp.	DN5
*ginger	*Hedychium gardnerianum*	WF10, WF12, WF14
glasswort	*Sarcocornia quinqueflora*	SA1, SA4, SA7
*gorse	*Ulex europaeus*	WL1, CL1, CL6, FI1, FI2, FI4
greenhood orchid	*Pterostylis* spp.	CL9
*grey willow	*Salix cinerea*	WL2, WL10, WL18, WL20
gumland grass tree	*Dracophyllum lessonianum*	WL3
gunnera	*Gunnera* spp.	DN5, CL9
hakea	*Hakea* spp.	WL1, FI2
half star	*Selliera radicans*	SA1, SA4, SA5, WL15, DN5, CL1
hangehange	*Geniostoma ligustrifolium*	CL9, FI2
harakeke, flax	*Phormium tenax*	SA4, SA7, WL10, WL11, WL18, WL19, WL20, DN2,
hard beech	*Nothofagus truncata*	WF5, WF13
heart-leaved kohuhu	*Pittosporum obcordatum*	MF2
hebe	*Hebe* spp.	SA7, WL20, CL1, CL6, CL9, FI4
*Himalayan honeysuckle	*Leycesteria formosa*	CL9, FI4
hinau	*Elaeocarpus dentatus*	WF6, WF10, WF11, WF13, WF14, MF4
hoheria	*Hoheria* spp.	MF2, FI4
Holloway's crystalwort	*Atriplex hollowayi*	DN2
houpara	*Pseudopanax lessonii*	CL1
hutu	*Ascarina lucida* var. *lucida*	MF4, MF22
iceplant		
*ivy	*Hedera helix* subsp. *helix*	CL6
*Japanese honeysuckle	*Lonicera japonica*	WL20, FI2, FI4
*Japanese walnut	*Juglans ailantifloia*	WL10
jersey cudweed	*Pseudognaphalium luteoalbum*	DN5
jointed twig rush	*Machaerina articulata*	WL19
kahikatea	*Dacrycarpus dacrydioides*	WF8, WF9, WF10, WF12, WF14, MF2, MF4, WL18
kaikomako	*Pennantia corymbosa*	MF2, FI4
kamahi	*Weimannia racemosa*	WF13, WF14, MF4, FI4
kanono	*Coprosma grandifolia*	FI4
kanuka	*Kunzea ericoides*	WF5, WF6, DN2, CL6, FI1, FI2, FI4
karaka	*Corynocarpus laevigatus*	WF5, WF6, WF8, WF10, CL1
karamu	*Coprosma robusta*	FI1, FI4
karo	*Pittosporum crassifolium*	SA4, CL1
kauri	*Agathis australis*	WF5, WF11, WF12, WF13, MF22
kauri grass	*Astelia trinervia*	WF11
kawakawa	*Piper excelsum*	CL1, FI2
kidney fern	*Trichomanes reniforme*	MF22
kiekie	*Freycinetia baueriana*	WF9, WF11, CL9
kiokio	*Blechnum* spp.	WL18, WL20, CL9
Kirk's pine	*Halocarpus kirkii*	WF11, MF22
knobby clubrush	*Ficinia nodosa*	SA1, SA4, DN5, CL1
kohekohe	*Dysoxylum spectabile*	WF5, WF6, WF8, WF9, WF10, WF11, WF12, WF13, WF14, CL1
kohuhu	*Pittosporum tenufolium*	FI1
kotukutuku	*Fuchsia excorticata*	FI4
kowhai	*Sophora* spp.	WF5, WF8, SA4, CL6, FI1, FI4
kuawa	*Schoenoplectus tabermontani*	WL19
kuta	*Eleocharis sphacelata*	WL10, WL11, WL19
lake clubrush	*Schoenoplectus tabernaemontani*	WL10, WL11, WL19
lancewood	*Pseudopanax crassifolius*	FI1
lemonwood	*Pittosporum eugenioides*	MF2

lepidosperma sedge	*Lepidosperma* spp.	WL1, WL11, DN5
lilaeopsis	*Lilaeopsis* spp.	WL15
lobelia	*Lobelia* spp.	WL15, DN5
*lupin	*Lupinus* spp.	DN2, FI1
lycopodiella	*Lycopodiella lateralis*	WL3
machaerina	*Macherina* spp.	WL1, WL2, WL3, WL10, WL11, WL18, WL19, CL9
mahoe	*Melicytus ramiflorus*	WF6, WF9, MF2, MF4, FI1, FI2, FI4
makamaka	*Ackama rosifolia*	WF10
mamaku	*Cyathea medullaris*	WF10, FI2, FI4
*Manchurian rice grass	*Zizania latifolia*	WL10, WL19
mangeao	*Litsea calicaris*	WF5, WF10, WF14, MF4
mangrove, manawa	*Avicennia marina* subsp. *australasica*	SA1
manuka	*Leptospermum scoparium*	WL1, WL2, WL3, WL11, WL18, WL20, DN2, DN5, CL6, FI2, FI4
mapere	*Gahnia xanthocarpa*	WF9
*marram	*Amophila arenaria*	DN2
matagouri	*Discaria toumatou*	DN2
matai	*Prumnopitys taxifolia*	WF8, MF2, MF4
maungaraho rock hebe	*Hebe saxicola*	CL6
melicytus	*Melicytus* spp.	SA4
*mercer grass	*Paspalum distichum*	WL15
*Mexican daisy	*Erigeron karvinskianus*	CL1, CL6
*Mexican devil	*Ageratina adenophora*	CL9
mingimingi	*Coprosma propinqua*	WL1, WL20, DN5
mingimingi	*Leucopogon* spp.	CL6
miro	*Prumnopitys ferruginea*	WF10, WF11, WF12, WF13, WF14, MF4, MF22
*mist flower	*Ageratina riparia*	CL9
*monkey apple	*Syzygium smithii*	WF10, WF12
*monkey musk	*Erythranthe guttata*	CL9
*moth plant	*Araujia sericifera*	CL1
mountain celery pine	*Phyllocladus alpinus*	MF22
mountain daisy	*Celmisia* spp.	CL6
mountain five-finger	*Pseudopanax colensoi*	MF22
mudwort	*Limosella* spp.	WL15, DN5
narrow-leaved maire	*Nestegis montana*	WF6, WF13
neinei	*Dracophyllum* spp.	MF22, WL1, CL6
needle-leaved neinei	*Dracophyllum latifolium*	WF11
nertera	*Nertera* spp.	SA5, CL9
New Zealand broom	*Carmichaelia* spp.	WL20, CL1, CL6
New Zealand celery		
New Zealand daphne	*Pimelea* spp.	SA4, CL6
New Zealand ice plant	*Disphyma australe* subsp. *australe*	SA7 , CL1
ngaio	*Myoporum laetum*	WF5, WF6, SA4, SA7, CL6, FI4
nikau	*Rhopalostylis sapida*	WF5, WF8, WF10, WF14
northern rata	*Metrosideros robusta*	WF8, WF10, WF11, WF12, WF13, WF14, MF4
northern tussock	??	CL1
oioi	*Apodasmia similis*	SA1, WL10, WL11, DN5, GT2
*old man's beard	*Clematis vitalba*	CL6, FI4
*pampas	*Cortaderia* spp.	CL1, CL6
parataniwha	*Elatostema rugosum*	WF9, CL9
Parkinson's rata	*Metrosideros parkinsonii*	MF22
pate	*Schefflera digitata*	FI4
pennywort	*Hydrocotyle* spp.	WL15, DN5
perching lily	*Astelia solandri*	CL6
pigweed	*Einadia* spp.	SA7, CL1
pin cushion	*Colobanthus* spp.	DN5
pine	*Pinus* spp.	WL1, CL1, CL6, FI1, FI2
pingao	*Ficinia spiralis*	DN2
pittosporum	*Pittosporum* spp.	FI2, FI4
plantain	*Plantago* spp.	WL15
poa	*Poa* spp.	SA7
pohuehue	*Muehlenbeckia* spp.	SA4

pohutukawa	*Metrosideros excelsa*	WF5, WF6, SA4, CL1
pokaka	*Elaeocarpus hookerianus*	MF2
pondweed	*Potamogeton* spp.	WL15, WL19
ponga	*Cyathea dealbata*	FI2, FI4
Poor Knights lily	*Xeronema callistemon*	CL1
prickly couch	*Zoysia minima*	SA5
prickly mingimingi	*Leptocophylla juniperina*	FI1
*privet	*Ligustrum* spp.	WF14, FI1, FI2, FI4
pseudopanax	*Pseudopanax* spp.	CL9, FI2, FI4
puka	*Meryta sinclarii*	WF5
pukatea	*Laurelia novae-zelandiae*	WF8, WF9, WF10, WF12, WF14, MF2, MF4
pukio	*Carex secta, C. virgata*	WL18, WL19
puriri	*Vitex lucens*	WF5, WF6, WF8, WF10, WF12, WF14
purua grass	*Bolboschoenus* spp.	WL10, WL19
putaputaweta	*Carpodetus serratus*	FI1, FI4
quintinia	*Quintinia serrata*	MF22
rangiora	*Brachyglottis repanda*	FI4
rata lianes	*Metrosideros* spp.	CL6, CL9
raukawa	*Pseudopanax edgerleyi*	WF10
raupo	*Typha orientalis*	WL10, WL18, WL19
red mapou	*Myrsine australis*	WF6, FI2, FI4
*reed canary grass	*Phalaris arundinacea*	WL19
rengarenga lily	*Arthropodium bifurcatum*	CL1
rewarewa	*Knightia excelsa*	WF5, WF6, WF8, WF10, WF11, WF12, WF13, WF14, MF4, FI2
ribbonwood	*Plagianthus regius*	MF2, FI4
rimu	*Dacrydium cupressinum*	WF9, WF10, WF11, WF12, WF13, WF14, MF4, MF22
*royal fern	*Osmunda regalis*	WL2, WL20
rush	*Juncus* spp.	WL11
saltmarsh 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
schoenus	*Schoenus* spp.	WL1, WL2, WL3, CL9
sea blite	*Suaeda novae-zelandiae*	SA1
*sea couch	*Elytrigia pycnantha*	SA1
sea grass	*Zostera muelleri* subsp. *novozelandica*	SA1
sea primrose	*Samolus repens*	SA1, SA5, SA7
sea rush	*Juncus krausii* var. *australiensis*	SA1
sedge	*Carex* spp.	WL11, WL15, WL18, WL20
shining karamu	*Coprosma lucida*	FI4
shore bindweed	*Calystegia soldanella*	SA4, DN2
shore celery	*Apium prostratum*	SA4, SA5, SA7, CL1
shore groundsel	*Senecio lautus* subsp. *lautus*	SA7
shore spurge	*Euphorbia glauca*	SA4
shrubby melicytus	*Melicytus* spp.	SA7
silver beech	*Nothofagus menziesii*	WF13
silver tussock	*Poa cita*	DN5
Sinclair's tamingi	*Epacris sinclairii*	WL3
slender clubrush	*Isolepis cernua*	SA5, CL1
small-leaved mahoe	*Melicytus* ??	MF2
small-leaved pohuehue	*Muehlenbeckia complexa*	SA7, DN2
snowberry	*Gaultheria* spp.	CL6
snow tussock	*Chionochloa flavicans*	CL6
soft mingimingi	*Leucopogon fasciculatus*	FI1
soft tree fern	*Cyathea smithii*	FI4
southern rata	*Metrosideros umbellata*	MF22, FI4

*Spanish heath	*Erica lusitanica*	WL1
sphagnum	*Sphagnum cristatum*	WL2, WL3
spider orchid	*Nematoceros* spp.	CL9
spiked sedge	*Eleocharis* spp.	WL11, WL15, WL19
spinifex	*Spinifex sericeus*	DN2
square sedge	*Lepidosperma australe*	WL11, DN5
sundew	*Drosera* spp.	WL3
supplejack	*Ripogonum scandens*	WF9, CL9
swamp astelia	*Astelia grandis*	WF9
swamp coprosma	*Coprosma tenuicaulis*	WL20
swamp helmet orchid	*Anzybas carsei*	WL3
swamp kiokio	*Blechnum minus*	WL20
swamp maire	*Syzygium maire*	WF9, WF10
swamp twig rush	*Machaerina juncea*	SA1
*sycamore	*Acer pseudoplatanus*	WL20, FI4
*tall fescue	*Schedonorus arundinaceus*	DN5
tamingi	*Epacris pauciflora*	WL1, WL2
tanekaha	*Phyllocladus trichomanoides*	WF5, WF11, WF12, WF13, SA4
tangle fern	*Gleichenia* spp.	WL2, WL3, WL11
taraire	*Beilschimiedia tarairi*	WF5, WF6, WF8, WF9, WF10, WF11, WF12
tauhinu	*Ozothamnus leptophyllus*	SA4, DN2, FI1
taupata	*Coprosma repens*	SA4, SA7, CL1
tawa	*Beilschimidia tawa*	WF5, WF6, WF8, WF9, WF10, WF11, WF12, WF13, WF14, MF4
tawari	*Ixerba brexioides*	WF10, WF13, MF4, MF22
tawapou	*Pouteria costata*	WF5, CL1
Taylor’s coprosma	*Coprosma taylorii*	WL20
tetraria	*Tetraria capillaris*	WL1, WL2
thin-barked totara	*Podocarpus hallii*	WF11, WF12, WF13, MF22
three-finger	*Pseudopanax colensoi* var. *colensoi*	MF22
titoki	*Alectryon excelsus*	WF5, WF6, WF8, WF9, MF2
toatoa	*Phyllocladus glaucus*	WF11, MF22
toetoe	*Austroderia* spp.	WL18, WL19, WL20, DN2, DN5
totara	*Podocarpus totara*	WF6, WF8, WF11, WF12, WF13, WF14, MF4
towai	*Weinmannia silvicola*	WF10, WF11, WF12, WF13, WF14, MF4, MF22
tree daisy	*Olearia* spp.	CL6, CL9, FI4
triglochin	*Triglochin striata*	DN5
tupari maunga	*Gahnia xanthocarpa*	WF9
turepo	*Streblus banksii*	MF2, CL1
*turf speedwell	*Veronica serpyllifolia*	WL15
turutu	*Dianella nigra*	CL6
tutu	*Coriaria* spp.	DN2, CL6, CL9, FI4
twiggy tree daisy	*Olearia virgata*	WL18, WL20
violet	*Viola* spp.	WL15
*wandering Willy	*Tradescantia fluminensis*	WF9, WF10, WF12
*water celery	*Apium nodiflorum*	WL19
water milfoil	*Myriophyllum* spp.	WL15, WL19
*water purslane	*Ludwigia palustris*	WL19
*water speedwell	*Veronica anagallis-aquatica*	WL19
*wattle	*Acacia* spp.	FI1, FI2
weeping matipo	*Myrsine divaricata*	WL18
wharangi	*Melicope ternata*	CL1
wharariki	*Phormium cookianum*	CL6, CL9
wheki-ponga	*Dicksonia fibrosa*	FI4
willowherb	*Epilobium* spp.	SA5, WL18, WL19, DN5
wind grass	*Lachnagrostis* spp.	WL15
wineberry	*Aristotelia serrata*	FI4
wire rush	*Empodisma minus*	WL2, WL3, WL11
woollyhead	*Craspedia* spp.	DN5
*woolly nightshade	*Solanum mauritianum*	CL1
yellow-silver pine	*Lepidothamnus intermedius*	MF22
*Yorkshire fog	*Holcus lanatus*	DN5

Anaphalioides trinervis		CL9
Brachyglottis turneri		CL9
Coprosma rhamnoides		FI1
Coprosma rugosa		WL20
Coprosma pedicellata	MF2	
Collospermum hastatum		CL6
Coloblanthus muelleri	SA5	
Glossostigma elatinoides		WL15
Hydrocotyle novae-zeelandiae		SA5
Lilaeopsis novae-zelandiae		DN5
Myriophyllum votschii	DN5	
Olearia crebra		CL9
Senecio rufiglandulosus		CL9