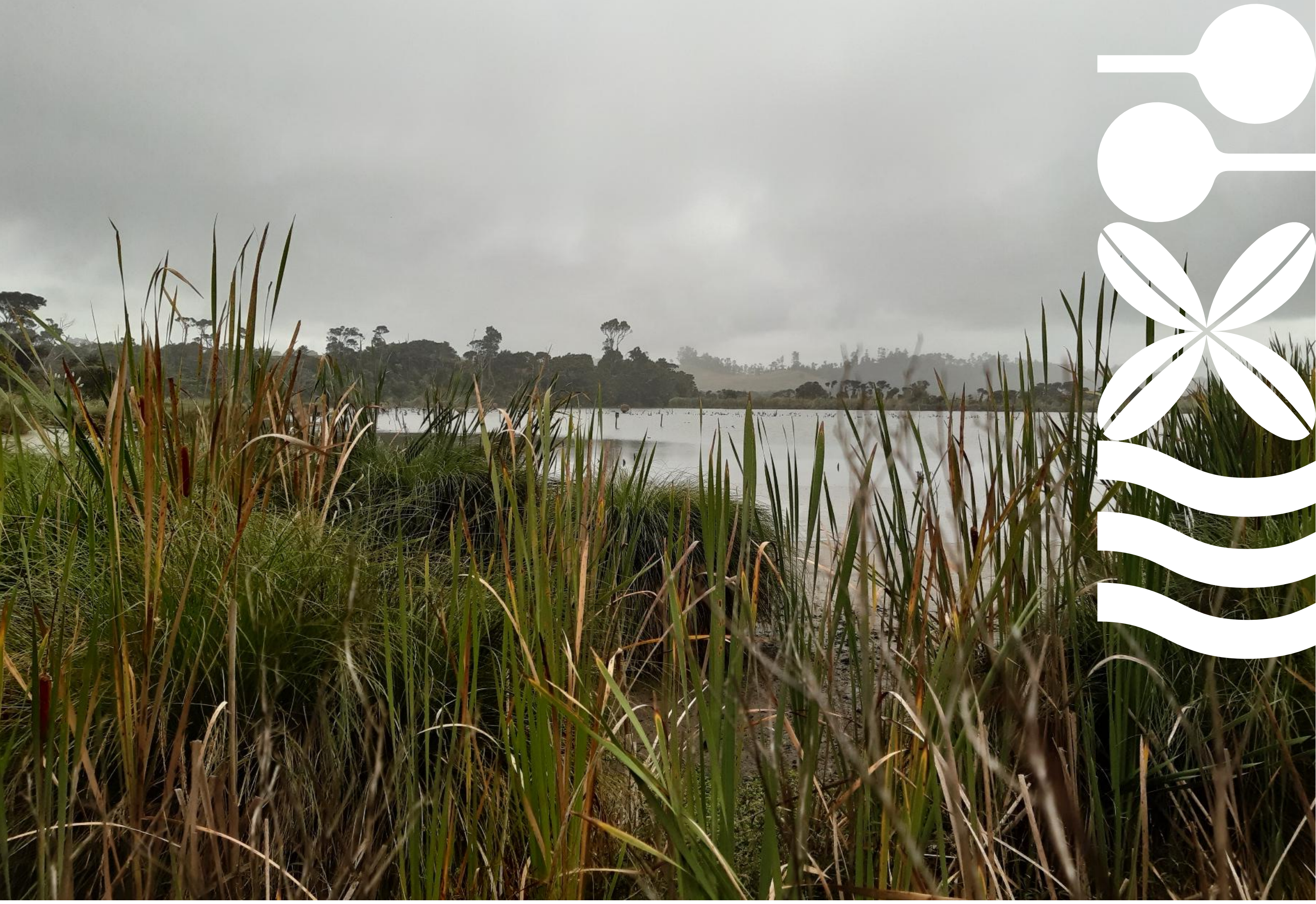

Wetland Ecological Integrity in Tāmaki Makaurau 2010-2024

State of the Environment Reporting

Georgianne J. K. Griffiths, Grant Lawrence

September 2025

Technical Report 2025/18

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Executive summary

Wetlands are permanently or intermittently wet areas that support natural ecosystems adapted to wet conditions, providing critical ecosystem services including flood attenuation, water purification, and biogeochemical cycling. An estimated 96% of original wetland extent in Tāmaki Makaurau has been lost through drainage and vegetation clearance for farming, settlement and urban development. As a result, all eight wetland ecosystems occurring in Tāmaki Makaurau are classified as threatened or at-risk according to International Union for Conservation of Nature (IUCN) criteria. The consequences of wetland loss have been severe for biodiversity, with wetland plants over-represented in New Zealand Threat Conservation Status lists.

Auckland Council's Terrestrial Biodiversity Monitoring Programme (TBMP) has established a network of permanent vegetation plots in 189 wetlands across the region, monitored every five years since 2010. This report analyses fifteen years of data to examine plant biodiversity and ecological integrity of wetlands across Tāmaki Makaurau. The sample of wetlands monitored is broadly representative of freshwater wetlands in the region. Most are swamp or marsh wetlands, though eight wetland classes are represented. Wetlands in the sample are surrounded by indigenous forest, exotic forest, rural and urban landcover on both public and private land. Wetlands range in size from 490 to 0.1 hectares, but most are small swamps or marshes less than 0.5 hectares surrounded by rural landcover.

The data reveals two key pressures impacting plant biodiversity in wetlands. First is the substantial burden of exotic and invasive pest plants. Exotic species compose half of all plant species recorded, while pest plants constitute 21% of all plant cover, with several species increasing in biomass over time.

Second, nutrient enrichment, especially from elevated nitrogen, appears to be changing indigenous plant communities. The data shows raupō biomass was highest and increased most where nitrogen levels were elevated relative to carbon, and areas of high raupō biomass were associated with significantly lower plant species richness. This pattern reflects global trends where nutrient loading drives shifts from diverse plant communities to monospecific stands. Increasing raupō biomass is a threat to biodiversity, but this species also has high cultural value to tangata whenua and its rapid growth will remove nutrients from the water during the growing season, protecting downstream water quality. Without harvesting however, a large proportion of these nutrients will be returned to wetlands during decomposition.

Analysis demonstrates the highly responsive nature of wetland vegetation, dominated by herbaceous perennial and annual plants. Plant communities showed substantial turnover in composition over the 15-year period, with communities generally diverging from their earlier states in a directional pattern consistent with ongoing anthropogenic pressures rather than natural variability.

The wetland condition, pressure and edge indices support the plant data in highlighting widespread threats. The Wetland Condition Index suggests 90% of wetlands are in excellent or good condition, but this assessment masks widespread problems since introduced plants are ubiquitous and only nine sites showed minimal predator impacts. The Wetland Pressure Index reveals 88% of wetlands face moderate to high anthropogenic pressure from pest animals, weeds and catchment-level processes including water quality decline. The Wetland Edge Index shows 40% of wetlands have good edge condition, with poor conditions characterised by inadequate buffers, stock access, drainage, and exotic plant dominance. Many wetlands that had better condition and lower pressure were on public land, and especially in Regional Parks, highlighting the importance of active management. The indices prove valuable in identifying what management should be targeted to improve wetland condition. More work is required nationally to set meaningful thresholds for wetland condition, pressure and edge indices to accurately reflect ecological integrity.

Analysis of threatened species reveals concerning trends. Of 50 nationally or regionally Threatened, At Risk or Data Deficient species recorded over 15 years, only eight showed small increases in biomass, while the remainder either declined or were detected in only one rotation, indicating high vulnerability to local extinction. Fifty-six per cent of these vulnerable species require wetland habitat to persist.

The data shows no systematic regional shifts in wetland hydrology described using a modified version of the Prevalence Index currently used in wetland delineation. Specific wetlands did show significant drying and wetting from various causes including forest regeneration, urbanisation, and plantation forestry effects. The modified Prevalence Index shows promise as a tool for monitoring wetland hydrology without resource-intensive hydrological monitoring, while raupō shows potential as an indicator of nutrient enrichment.

This technical report demonstrates the value of long-term monitoring by enabling detection of changing patterns across wetlands in Tāmaki Makaurau. The monitoring data will only increase in value and sensitivity over time.

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List of acronyms and abbreviations

AUP	Auckland Unitary Plan
AC	Auckland Council
DOC	Department of Conservation
IUCN	International Union for Conservation of Nature
LCDB	Landcover Database
MfE	Ministry for the Environment
SEA	Significant Ecological Areas
TBMP	Terrestrial Biodiversity Monitoring Programme
WMA	Wetland Management Area

1 Introduction

1.1 Wetland ecosystem services

Wetlands are permanently or intermittently wet areas, shallow water, and land-water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions (Resource Management Act 1991). They can form where there is poor drainage or an accumulation of water and are common in topographically low-lying positions that receive water, nutrients, sediment and propagules from the surrounding catchment. They are also common where land meets water at the edges of streams, rivers, lakes and estuaries. As receiving environments in the wider catchment, wetlands provide a disproportionately high level of ecosystem services compared to other terrestrial ecosystems (TEEB 2013). Wetlands can act as natural reservoirs, accumulating floodwater, slowing flows and reducing peak water levels which all contribute to flood attenuation. Coastal wetlands provide a physical barrier, protecting coastal land from storm surge. Many of these ecosystem functions point to the resilience (described as resistance to perturbations and recovery from them) of wetlands, which experience some degree of infilling or erosion cyclically, and sometimes suddenly in response to storm events. Wetlands play a role in biogeochemical regulation of greenhouse gases by acting as a sink for carbon, depending on wetland type, water level fluctuations and how well wetlands are protected and maintained (Ausseil et al 2013, Goodrich et al 2017, Helfter et al 2021, Easdale et al 2022, Guan et al 2025). Wetlands are frequently described as the kidneys of the natural environment for their role in removing sediment, nutrients and contaminants from the water. Saturated soils promote microbial processes that result in both nitrogen fixation, making nutrients available to plants, and denitrification, converting nitrates to gas and improving water quality (Clarkson et al 2013). The combination of shallow water, receiving environments and microbial processes can promote vegetation growth, making wetlands highly productive. Wetlands in Tāmaki Makaurau support a wealth of biodiversity, from the tiny water-meal (*Wofflia australiana*) with leaves less than a millimetre long, to the tall stems of kuta (*Eleocharis sphaceolata*), from the nationally threatened marsh fern (*Thelypteris confluens*) to the abundant raupō. Wetlands also provide food, shelter and breeding sites for a wide variety of birds, fish, amphibians, and invertebrates. In Aotearoa New Zealand, wetlands have significant cultural, spiritual, historic and economic value to tangata whenua (Taura et al 2017). For many iwi and hapu, wetlands form an important component of their whakapapa, with the mauri (or life force) of the wetland reflecting the well-being of the people. Many of the resources that can be obtained from wetlands have high cultural value, including plants for eating or weaving, and a range of fish, birds and invertebrates that are highly valued.

1.2 Wetland vegetation and classification

Wetland flora is highly biodiverse and varied in form with some species highly adapted to the stresses imposed by flooding. Swamp forest would once have been common across Tāmaki Makaurau with kahikatea (*Dacrycarpus dacryioides*), pukatea (*Laurelia novae-zelandiae*), maire tawake (*Syzygium maire*), raupō (*Typha orientalis*), tī kōuka (cabbage tree, *Cordyline australis*) and harakeke (flax, *Phormium tenax*) once common inland, grading into saltmarsh with oioi (*Apodasmia similis*) and searush (*Juncus kraussii subsp. australiensis*) in coastal areas. Wetland vegetation is often dominated by monocots, including grasses, reeds, rushes, sedges, harakeke and tī kōuka (Johnson and Brooke 1998). Some species such as *Bolboschoenus* species and raupō are summer-green, meaning they grow in summer and die back in winter. Raupō grows well in fertile wetlands; during summer months the foliage responds rapidly to nutrient influx which then dies back in winter.

Two wetland classification systems are commonly used in New Zealand. The wetland classes of Johnson and Gerbeaux (2004), are characterised by their substrate (mineral to organic), water regime, fertility, pH and salinity, to produce nine classes: swamp, marsh, fen, bog, seepage, shallow water, ephemeral wetland, pakihi/gumland and saltmarsh, all of which occur in Tāmaki Makaurau. The wetland classes of Johnson and Gerbeaux (2004) are commonly used nationally. The wetland ecosystems identified by Singers and Rogers (2014) are based on a structured list of vegetation compositions for Aotearoa New Zealand based firstly on salinity (saline versus freshwater wetlands), then water fertility, mean annual temperature, substrate and landform. Singers and Rogers (2014) identified 22 wetland ecosystems nationally, of which nine occur in the Auckland region, though one (Bamboo rush, greater wire rush, restiad rushland, WL3) is now regionally extinct (Singers et al 2017). These wetland ecosystems grade into each other as the abiotic and biotic conditions change, for example Oioi restiad rushland/reedland (WL10) can grade into saltmarsh on coastal margins, or into Machaerina sedgeland (WL11) in freshwater environments. Wetlands can also occur as mosaics of different ecosystem types, such as the dynamic wetland-dune mosaic at Whatipu, formed of shifting areas of Machaerina sedgeland (WL11), Raupō reedland (WL19), Herbfield (WL15), Oioi, knobby clubrush sedgeland (DN5) with naturally uncommon dune slack, Spinifex, pīngao grassland/sedgeland (DN2), and some Treeland at the base of the coastal cliffs. There has been some difficulty applying Singers et al (2017) ecosystems; in Tāmaki Makaurau this is particularly for lowland wetlands dominated by *Carex* species, and novel vegetation communities that contain a high proportion of exotic and pest plants.

1.3 Wetland extent in Tāmaki Makaurau

One of the defining characteristics of Tāmaki Makaurau is its coastal setting, with narrow distances between east and west coasts, large harbours and estuaries that support an abundance of estuarine, saline and brackish wetlands. Inland, palustrine swamp, marsh, kahikatea (*Dacrycarpus dacrydioides*) dominated swamp forest and lakes were abundant in pre-human times. These formed in the basins and flat-bottomed valleys of hill country, for example surrounding the Hūnua Ranges, the flat and fertile lowlands surrounding the Kaipara, Manukau and Waitemata harbours, in shifting coastal sands, especially on Te Korowai-o-te-Tonga / South Kaipara Peninsula and where lava flows from volcanic activity blocked natural drainage (Lindsay et al 2009).

Across Aotearoa New Zealand, approximately 90% of wetland extent has been lost in the past 150 years, one of the highest rates of wetland loss globally (Dymond et al 2021). Only 4.9% of historic extent remains in the North Island, with losses greatest in areas with high population densities and development (Ausseil et al 2011). For Tāmaki Makaurau, it is estimated that only 4% of freshwater wetlands remain (Lindsay et al 2009). Evidence suggests some wetland loss continues in Tāmaki Makaurau, mostly of estuarine ecosystems (Denyer and Peters 2020; Griffiths and Lawrence 2021). Ongoing wetland loss and degradation in Aotearoa New Zealand, despite a range of protections and rules, occurs in part as a result of variation in the strength of rules and limited resources for enforcement (Denyer and Peters 2020). Most wetland loss has been through drainage and vegetation clearance for farming, settlement and urban development.

The current wetland extent in Tāmaki Makaurau was systematically mapped in 2017 and approximately 17,250 ha of wetland identified (Lawrence and Bishop, 2017). Wetlands were 65% estuarine (saline associated with estuaries, tidal reaches), 22% palustrine (freshwater wetlands fed by rain, ground water or surface water) and 11% water bodies (including natural lakes). Riverine (associated with rivers streams and other channels) and lacustrine (associated with the margins of lakes and open water bodies) were the rarest forms of wetland (<2% combined). The mapping underestimates ephemeral, forested, lacustrine and riverine wetlands, due to difficulty in detecting seasonal variation in vegetation cover and hydrology from single timestamp imagery and detecting wetland below canopy in aerial imagery. It also has limited accuracy in detecting wetlands <0.1 ha.

Palustrine wetlands comprised 95% of the total area of freshwater wetlands. Of the palustrine wetlands mapped in Tāmaki Makaurau, 76% were swamp, 13% marsh, and the remaining 11% composed of fen, bog, seepage, shallow water, ephemeral wetland and pakihi/gumland. Most palustrine wetlands in Tāmaki Makaurau were small (98% <10ha, 58% <0.5 ha in size) and formed less than 10% of the total palustrine area but made up a significant proportion of water bodies in Tāmaki Makaurau (Lawrence and Bishop 2017). Small wetlands provide considerable ecological value and have been shown to contribute disproportionately to the conservation of rare, threatened and at-risk plant species (Richardson et al 2014, Dymond et al 2021).

1.4 Wetland pressures

As a result of wetland loss, all eight of the wetland ecosystems in Tāmaki Makaurau are classified as threatened or at-risk according to IUCN criteria (Singers et al 2017). The consequences of wetland loss have been severe for biodiversity. It is estimated that 21% of indigenous vascular plants are wetland specialists (McGlone et al 2001), and aquatic and wetland plants are over-represented in the New Zealand Threat Conservation Status lists of threatened, at-risk and data deficient species, indicating the pressures aquatic and wetland systems are under (de Lange et al, 2017). Several threatened and at-risk bird and fish species are declining as a result of historical wetland loss, predatory mammals, declining water quality and other pressures (Bloxham et al 2023, Woolly et al 2024). Less well documented are the impacts of invasive wasps (*Vespula* and *Polistes* species); these species thrive in wetland ecosystems and are known to consume and seriously deplete invertebrate fauna, particularly butterflies and moths (Beggs et al 2011; Lefort et al 2020a; Lefort et al 2020b).

Remaining wetlands, especially those that are small, fragmented or within highly modified landscapes such as urban or rural land cover, are sensitive to further degradation from a wide range of anthropogenic activities. Wetlands in Aotearoa New Zealand continue to be under pressure from drainage, with a greater area exposed to drainage than previously predicted, and the zone of potential effect from drains underestimated (Burge et al 2023). Catchment level land-use activities can reduce water quality through increased sediment, nutrient and contaminant input, and affect hydrology. Vegetation clearance can increase run-off while exotic plantations reduce run-off from a catchment, increasing impervious area in the catchment with urbanisation can increase or decrease water draining into a wetland depending on the engineered stormwater treatment, water allocation can reduce water levels, etc. Disturbance through grazing and trampling by farm animals continues to occur where wetlands are unfenced in farmland.

Invasive pest plants represent a significant threat to wetland biodiversity and ecosystem functioning by displacing indigenous species locally, altering wetland hydrology and disrupting nutrient cycles (Bodmin 2012). One example is the carnivorous bladderwort *Utricularia australis*, which has severely decline in Northland in response to competition from the invasive bladderwort *U. gibba*, which has spread throughout Northland, Auckland and Waikato. The invasive *U. gibba* was recorded at three Auckland wetlands in the TBMP but there are no records of the native species. A recent study of New Zealand wetlands using eDNA showed that ≥50% of species detected were exotic (Bird et al 2024).

Wetland types vary considerably in their nutrient content, wetlands fed by rainwater will be low-nutrient while wetlands fed predominately by groundwater will have low to medium nutrient levels (Johnson & Gerbeaux 2004). As shallow receiving environments wetlands are vulnerable to changes in nutrients and sedimentation. Wetlands in pastoral or horticultural catchments are more likely to be enriched by high-nutrient run-off. While wetlands can help remove nutrients such as phosphorus and nitrogen from downstream waters (Tomer et al 2009), nutrient enrichment of wetlands can cause major changes in plant composition and wetland ecology. Increasing nutrient levels promote plant growth, especially where plants are nutrient limited. The resulting competition for light will favour fast-growing species such as raupō, and there can be shifts from diverse communities to communities dominated by a few species (Cooke et al 1990). Prolific plant growth can block water movement and increase sedimentation and evapotranspiration, further decreasing water levels. Litter (or dead plant material) produced in eutrophic wetlands has a higher nitrogen and phosphorus content and breaks down readily, releasing these nutrients back into the water. This further enrichment of the water can lead to algal blooms and anaerobic (de-oxygenated) conditions (Sorrell 2010).

Climate change will impact wetlands through more extreme drought and risk of fire damage, sea-level rise impacting coastal wetlands, increased frequency and severity of flood and storm surge events, as well as exacerbating existing pressures, including from pest plants and animals (Bishop and Landers 2019, Macinnis-Ng et al 2021). Following the extreme rainfall events of Cyclones Hale and Gabrielle in 2023, a study by Manaaki Whenua Landcare Research looked at wetland responses using Wetland Condition Index and Wetland Pressure Index data from the TBMP in Tāmaki Makaurau and from Hawkes Bay (Allen et al 2024). Data showed that wetlands took on large volumes of water during and after the storms, with flooding still evident after six months at some wetlands. In Tāmaki Makaurau, there were no overall changes in wetland condition or pressure post-cyclones, although wetland pressures increased more on private land. Some component pressure scores did change however, with increased pressure from key undesirable plants (pest plants) and poorer water quality (mostly from increased sedimentation), and reduced pressure from lower wetland isolation (Allen et al 2024). In Hawks Bay, there was no change in the wetland pressure score post-cyclones but the Wetland Condition Index decreased by 4% in response to increased sedimentation, damage to native vegetation and increase in mammalian predator impacts. The results indicated that wetlands moderated water flow. In the short-term, wetlands were largely resilient to the impacts of such extreme rainfall and flooding events, although individual wetlands in Hawks Bay were more severely impacted by sedimentation. In the longer term however, and with increased frequency of extreme weather events, increased sedimentation, pest plant and mammal pest pressure could have cumulative negative impacts on wetland ecological integrity (Allen et al 2024).

1.5 Wetland policy and monitoring

Avoiding further loss or degradation of wetlands is a priority of the National Policy Statement for Freshwater Management (NPS-FM, 2020). The NPS-FM focuses on protecting natural inland wetlands (defined as per the Resource Management Act but with several exclusions). It excludes wetlands in the coastal marine area; wetlands that have been deliberately constructed (unless they were constructed to offset impacts on or restore a former natural inland wetland); wetlands that have developed around a deliberately constructed waterbody; geothermal wetlands; or wetlands within an area of pasture used for grazing that have >50% exotic pasture species cover (except where the wetland is identified as a habitat supporting a threatened species).

Currently, the NPS-FM requires Auckland Council to map and monitor the condition of natural inland wetlands which are 0.05 ha or greater in extent (or smaller if known to contain threatened species), and to have policies, rules and methods in place to ensure no net loss of extent or value of those wetlands. Compulsory values to monitor are ecosystem health, including the five biophysical components water quality, water quantity, habitat, aquatic life, and ecological processes, together with human contact, threatened species and mahinga kai. However, the government is currently (May 2025 to July 2025) consulting on proposed amendments to existing freshwater national direction including the NPS-FM (MfE 2025a). Some key recommendations include amending the definition of "natural inland wetland" to remove pasture exclusion (part (e) of the definition) such that pastoral wetlands would be included as natural inland wetlands, but permitted activities would be introduced for farming in and around all natural inland wetlands, and a recommendation to remove the mandatory mapping requirements from clause 3.23 of the NPS-FM 2020 and devolving the responsibility to regional councils to determine how best to monitor wetlands in their areas (MfE 2025b). These proposals have prompted concern from freshwater experts in Aotearoa New Zealand (Prickett & Joy 2024).

Auckland Council's regional framework for wetland protection includes the Significant Ecological Areas (SEA) overlay and the Wetland Management Areas (WMA) overlays. These operate through restrictions in permitted development or activity, as part of the Auckland Unitary Plan (AUP) (Operative in Part) and continue to operate in alignment with national direction. These overlays are available to view on the Auckland Council GeoMaps website.

Terrestrial SEAs were designated based on the presence of significant indigenous vegetation or habitat of indigenous fauna located either on land or in freshwater environments. These areas of ecological significance across Tāmaki Makaurau have been mapped in the SEA overlay and listed in schedule 3 and 4 of the AUP in fulfilment of section 6(c) of the Resource Management Act (1991) to protect areas of ecological significance. The AUP currently includes 105 "significant wetlands" scheduled within the WMA overlay. These are governed by objectives and policies contained within Chapter D9 – WMA Overlay, and rules within E3 – Lakes, rivers, streams and wetlands. The WMA overlay imposes more stringent controls than those generally applied to wetlands, particular in relation to vegetation clearance, earthworks, and hydrological modification. The list of wetlands scheduled as WMAs is contained in Schedule 1 of the AUP. Auckland Council conducts monitoring and reporting on the effectiveness and efficiency of plans within the AUP according to Sections 35(2)(b) of the Resource Management Act, that is separate to this State of the Environment reporting.

1.4 This report

Auckland Council's Terrestrial Biodiversity Monitoring Programme (TBMP) was established in 2009 to monitor plant and bird biodiversity and assess condition in forests, wetlands and dunes across Tāmaki Makaurau as part of State of the Environment monitoring required under Section 35(2A) of the Resource Management Act 1991, legislation currently undergoing reform. This report analyses plant data, condition, pressure and edge indices and abiotic parameters from the TBMP wetland plot network, to examine plant biodiversity and wetland ecological integrity in Tāmaki Makaurau.

This report is one of a series of technical publications prepared in support of *Te oranga o te taiao o Tāmaki Makaurau – The health of Tāmaki Makaurau Auckland's Natural Environment in 2025: a synthesis of Auckland Council State of the Environment reporting*.

Related reports on bird biodiversity (Fessardi et al 2025) and forest biodiversity (Griffiths et al 2025) will be published as part of this series. All related reports (past and present) are published on the Knowledge Auckland website. All public data supporting this report can be requested through our Environment Auckland Data Portal.

2 Methods

2.1 The wetland plot network

The wetland plot network was established in 2010 and aimed to generate an unbiased, representative sample of freshwater palustrine wetlands for monitoring across Tāmaki Makaurau (Denyer et al 2011). The network uses a spatially stratified systematic sampling approach using a 4-km-grid. The wetland closest to the centroid of each grid square was selected for sampling. Selected wetlands had to be large enough to contain 80% of a 15 x 15m wetland plot (at least 180m^2 of the 225m^2 plot). The smallest wetland monitored was 0.1 ha or 1,000m^2 in size. A total of 189 wetlands are used to represent regional (Tier 1) wetland ecological integrity (Figure 1).

On each wetland visit, standardised measurements are taken from fixed-sized plots, a modification to variable plot sizes used in national protocols (Clarkson et al 2004) to generate more comparable quantitative data. A 15 x 15m plot contains one nested 10 x 10m subplot and nine 2 x 2m presence/absence sub-plots (Figure 2). At each wetland site, vegetation mapping, three 10-minute bird counts and two five-minute wasp counts are undertaken.

Plots are visited on a 5-year rotation with rotation 1 occurring from 2010-2014, rotation 2 from 2015-2019, and rotation 3 from 2020-2024. Rotation 4 started in 2025. Most permanent plots (n = 182) were established between 2010 and 2014 (rotation 1). Seven plots were then established between 2015 and 2019 (rotation 2) where previously unmapped wetlands were identified in grid squares without a plot or were closer to the grid centroid than those already established. The number of plots measured in any rotation varies due to the number of permissions granted from private landowners or other access restrictions. Additionally, in the last rotation (2020-2024) fewer plots were visited as a result of the Covid-19 lockdown restrictions (Rotation 1, 2010-2014, 182 plots; Rotation 2, 2015-2019, 177 plots; Rotation 3 2020-2024, 163 plots).

A series of permanent replicate plots have also been established at large, or high conservation wetlands in the Auckland region (Tier 2, Table 1). There are 12 public and two privately owned sites. These replicate plots use the 10 x 10m national wetland plot protocol with one nested 2 x 2m sub-plot. No vegetation mapping or bird monitoring is conducted at replicate plot sites.

Figure 1. Location of wetland plots (Tier 1 and Tier 2) in the TBMP wetland monitoring network.

Table 1. Numbers of wetland plots monitored in Tier 1 and Tier 2 in each rotation.

Tier	Location	Tenure	Rotation 1	Rotation 2	Rotation 3	Total plots
Tier 1	Regional	Public & Private	182	177	126	189
Tier 2	Awhitu	Public	5	0	0	5
Tier 2	Claris Reserve, Aotea	Public & Private	10	10	0	10
Tier 2	Kaitoke, Aotea	Public	16	0	0	16
Tier 2	Kohuora, Papatoetoe	Public	4	0	0	4
Tier 2	Le Roys Bush, Birkenhead	Public	6	0	0	6
Tier 2	Onepoto, Northcote	Public	4	4	0	4
Tier 2	Pakiri Regional Park, Rodney	Public	0	6	0	6
Tier 2	Shakespear Regional Park	Public	0	14	0	14
Tier 2	Soldiers bay, Birkenhead	Public	5	5	0	5
Tier 2	Stonefields, Ihumatao	Public	3	0	0	3
Tier 2	Te Henga/Bethells, Waitākere Ranges	Private	10	10	0	10
Tier 2	Te Muri Regional Park, Rodney	Public	8	7	0	8
Tier 2	Waiatarua, Remuera	Public	6	10	0	10

2.2 Field methods

Field monitoring methods capture a wide range of information about the wetland, its plants, birds, wasps and water. Several measures aim to describe the entire wetland or the % of wetland that can reasonably be seen and explored, others focus on the 15 x 15m permanent vegetation plot. Wetland field visits are made between January and March each year, when lower water levels facilitate access and many plants are flowering to assist with species identification. The team visiting the wetland include a team leader, botanist, ornithologist and field assistant. All data is recorded by electronic data capture systems using DataPlus on Mesa 3 or Allegro units. Field visits take between 3-6 hours depending on the vegetation diversity and ease of movement. Full details of the current TBMP wetland protocol are available on request (Environmentaldata@aklc.govt.nz).

2.2.1 Whole wetland

(a) Classification: On each plot visit the wetland system, subsystem, class and form are classified according to Johnson and Gerbeaux (2004).

(b) Wetland overview: The wetland vegetation is delineated and classified according to 33 terrestrial structural classes, e.g. reedland, rushland, etc. For each vegetation type, the % of the wetland it covers is estimated and the vegetation described using the Atkinson system (Atkinson, 1985). The Atkinson system is based on the canopy layer as seen from a birds-eye view. Any plant or ground cover that is open to the sky is part of the Atkinson canopy. For the tallest height tier, the % cover of up to three dominant species is recorded using four cover classes (1 – 9%, 10 – 19%, 20 – 50% and >50%). This is repeated for each decreasing height tier. The designation of height tier is very subjective and relative to what plants are present, there can be up to four height tiers.

(c) Wetland outlook: Using a high point to overlook the system (where available), a pre-printed aerial map is used to delineate, name and describe the main vegetation types using the Atkinson system (Atkinson 1985). Additional features recorded on the map include drains, fire damage, vegetation clearance, stock damage or major weed infestations. Where it is not possible to overlook the entire wetland, the area (%) of the wetland described is estimated.

2.2.2 Wetland Indices

Three semi-quantitative indices are scored to assess the wetlands: Wetland Condition Index (WCI) and Wetland Pressure Index (WPI) according to nationally standardised methods in the Wetland Monitoring Handbook (Clarkson et al. 2004), and Wetland Edge Index (WEI) developed for the TMBP (Denyer et al 2011). These indicators are scored following field reconnaissance of the whole wetland (where practical), consideration of historical and other information, and interpretation of the plot data.

(a) The **wetland condition index** (WCI) assessment scores sub-indicators of five attributes within the wetland (hydrological integrity, physicochemical parameters, ecosystem intactness, browsing, predation and harvesting regimes, dominance of native plants) on a 0-5 scale (0 = no modification, 5 = extreme modification) for change from a presumed pre-human baseline condition. The wetland condition index is the sum of the sub-indicators, to give a total out of 25. To categorise wetland condition the 0 – 25 scale was divided into evenly distributed bands described as Excellent ≥ 20 – 25; Good ≥ 15 – 19; Moderate ≥ 10 – 15 and Poor / Degraded < 10, with the National Bottom Line set at <10 (Clarkson et al 2015).

(b) The **wetland pressure index** (WPI) assessment scores six sub-indicators within the immediate catchment surrounding the wetland (catchment hydrology, water quality, animal pest presence, key undesirable plant species, introduced vegetation, wetland isolation) on a 0 – 5 scale (0 = no pressure, 5 = extreme pressure) for change from a pre-human baseline. The wetland pressure index is the sum of the sub-indicators, to give a total out of 30. When the Wetland Pressure Index scores ≥ 20, or an individual component scores ≥ 4, the wetland is considered to be under High pressure which could potentially cause changes in condition (Clarkson & Bartlam 2017). Using the same evenly distributed bands used for the WCI, Medium pressure can be interpreted as ≥ 10 – 19; Low pressure < 10.

(c) The **wetland edge index** (WEI) assessment uses a perimeter walk to score six sub-indicators at the wetland edge to detect imminent threats to wetland condition (shape index (a desk-based measure of area to perimeter), stock access, weed density, canopy dieback, perimeter buffer, perimeter drainage) on a 0 – 5 scale (0 = poor condition/high risk, 5 = good condition/low risk). For small wetlands the entire perimeter can be walked, but in larger wetlands only a portion of the perimeter will be walked, though site maps and the wetland overview may help with some indicators (e.g. buffer). The wetland edge index is the sum of the sub-indices, to give a total out of 30. Using the same evenly distributed bands used for the WCI, scores for the WEI can be interpreted as Good ≥ 20 – 30; Moderate ≥ 10 – 19; or Poor <10.

2.2.3 Vegetation plot

A series of vegetation measurements are taken within a 15 x 15m permanent vegetation plot, containing a nested 10 x 10m subplot and nine 2 x 2m subplots (Figure 2).

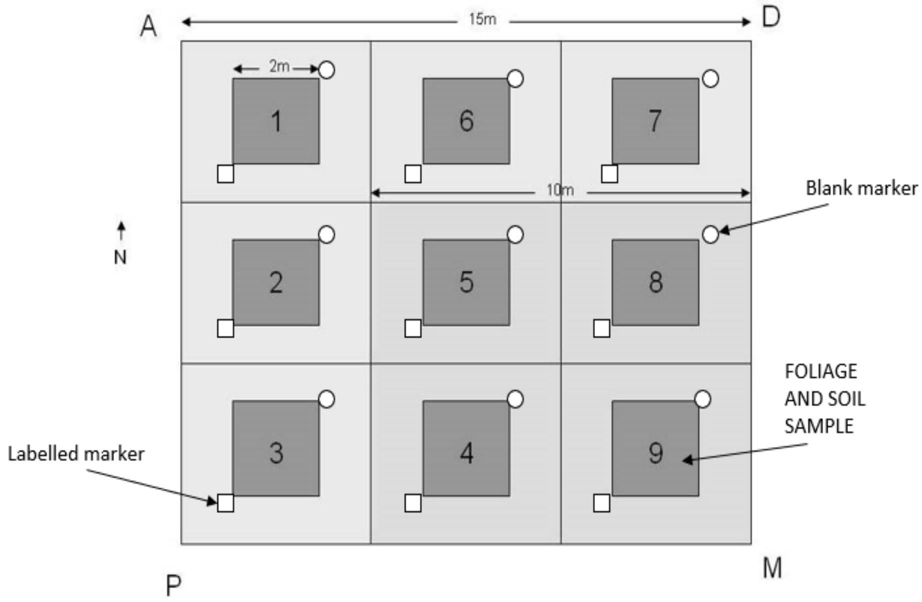

Figure 2. The layout of a 15 x 15m permanent vegetation plot

(a) In the 15 x 15m plot, two sets of measurements are made. First, the presence of all live vascular plant species are recorded in three height tiers (>2m, 0.3-2m, and <0.3m). The phenology (stage of development, e.g., flowering, fruiting, mature) of species is recorded only for those species not captured in the 10 x 10 and 2 x 2 plots. Second, an Atkinson vegetation description is made. For the tallest height tier, the % cover of up to three dominant species is recorded using four cover classes (1 – 9%, 10 – 19%, 20 – 50% and >50%). This is repeated for each decreasing height tier. The designation of height tier is very subjective and relative to what plants are present, there can be up to four height tiers.

(b) In the 10 x 10m subplot, two sets of measurements are made. First, a recce is recorded by estimating the percentage cover of live and dead (separately) foliage of all vascular plant species in three fixed height tiers[1] (>2m, 0.3-2m, and <0.3m). Foliage that hangs or leans into the subplot is included, regardless of whether it is rooted in the subplot. Percentage cover values are intended as a surrogate estimate of biomass per species in each height tier. The phenology of all species is recorded. Second, an Atkinson vegetation description is made. For the tallest height tier, the % cover of the three dominant species is recorded using four cover classes (1 – 9%, 10 – 19%, 20 – 50% and >50%). This is repeated for each decreasing height tier.

[1] This is a departure from the national protocols of Clarkson et al (2004) who propose a variable tier approach based on a bird's eye view of the canopy (any vegetation open to the sky), understory and ground cover (the latter two being somewhat subjective). Using fixed height tiers is more robust for monitoring, being able to be consistently applied among users and over time.

(c) Within each of the nine **2 x 2m subplots** the presence of live foliage of all vascular plant species is recorded in three height tiers (>2m, 0.3-2m, and <0.3m). The phenology of all species is recorded. The purpose of the 2 x 2 m subplots is to provide semi-quantitative data on species frequency and distribution and was developed for the Auckland Council TBMP (Denyer et al 2011). This approach is likely to over-estimate the abundance of small but widely distributed species such as *Eleocharis acuta* and underestimate the abundance of clustered species.

(d) In the **15 x 15m bird's eye sketch** a rough map of the 15 x 15m vegetation plot is sketched delineating and naming the main vegetation types, showing the canopy of any large trees, and areas of open water, channels or other features.

Vegetation data is used to identify indigenous, weed (Regional Pest Management Plan, 2020 and/or the Department of Conservation's published list of environmental weeds (MacAlpine and Howell 2024)) and rare or threatened plant species (de Lange 2024, Simpkins et al 2022). Species are also categorised according to their wetland status (Clarkson et al 2021) to identify changes in wetland hydrology.

2.2.4 Phenology

Since 2021, the phenology of plant species has been recorded for all species in the 10 x 10m and 2 x 2m subplots and for those species in the 15 x 15m plots not already recorded from the 10 x 10 or 2 x 2m subplots.

For non-dicots (e.g. ferns, grasses), species are either non-fertile, or the % of the population that is fertile is recorded in four abundance classes (1 – 25%, 26 – 50%, 51 – 75%, 76 – 100%, Table 2).

For dicots, species are either non-fertile or the % of the population occurring in each of seven developmental stages is recorded in four abundance classes (1 – 25%, 26 – 50%, 51 – 75%, 76 – 100%, Table 2). Most species will have multiple developmental stages at any one time.

These data are not analysed in this report.

Table 2. Phenology measurements

	development stage		abundance	
Non-dicots (monocots, ferns)	N	Non-fertile		
	F	Fertile	1	1-25% of individuals in plot
			2	26-50% of individuals in plot
			3	51-75% of individuals in plot
			4	76-100% of individuals in plot
Dicots	N	Non-fertile		
	BE	Bud Early		
	BL	Bud Late	1	1-25% of individuals in plot
	FLE	Flower Early	2	26-50% of individuals in plot
	FLF	Flower Full	3	51-75% of individuals in plot
	FLL	Flower Late	4	76-100% of individuals in plot
	FRI	Fruit Immature		
	FRM	Fruit Mature		

2.2.5 Bird counts and playbacks

At each wetland monitored, the location of three bird monitoring stations is established. Each station should be between 100m and 200m apart and located to maximise wetland bird detection based on habitat suitability and distance from roads or other anthropogenic disturbance. Where this is unclear, bird monitoring stations should be located away from the direction the wetland was accessed from.

At each station two bird monitoring techniques are used. First, a ten-minute bird count is completed. During minutes one to five, any bird species seen or heard is recorded with an estimate of its distance from the station using eight distance classes (0-10m, 11-20m, 21-40m, 41-60m, 61-100m, 101-150m, >150m, Flying Over). During minutes six to ten, only species not already captured are recorded. Second, three playback recordings are used to help detect three cryptic and declining wetland bird species, the mātātā (fernbird, B*owdleria punctata*), moho pererū (banded rail, *Gallirallus philippensis*) and pūweto (spotless crake, *Porzana tabuensis*). Bird species are categorised as indigenous (native and endemic) or introduced.

Analysis of bird data from the wetland TBMP can be found in Landers et al (2021) and Fessardi et al (2025).

2.2.6 Wasp counts

In 2021 we started to conduct two five-minute wasp counts at the same time as the second and third bird counts. All *Vespula* or *Polistes* wasps are counted separately within a range of 20m and 360° radius. Wasp counts are conducted between 10am and 5pm when the temperature > 18 °C, and not during rain or strong wind. This method is adapted from Schmack et al (2020) but using a smaller distance (20m) to maintain accurate identification. These data are not analysed in this report.

2.2.6 Abiotic parameters

A set of abiotic parameters have been measured from the water, soil and foliage intermittently since 2010, and consistently since 2020. Soil samples were tested in 2012 to 2015 (for soil pH, field bulk density, carbon and phosphorus only) and then from 2020 onwards (for soil pH, field bulk density, soil gravimetric water content, soil moisture (%), carbon, nitrogen and phosphorus content). Only data from 2020-2024 are examined in this report. These abiotic parameters can be used to assess some aspects of water quality.

(a) Water: Water measurements are made during the field visit when there is sufficient water to test. Measurements taken in subplot 9 include water table (water level relative to average substrate height, cm), electrical conductivity (µS/cm), pH, temperature (°C).

(a) Soil: Two soil cores are taken from the south-east corner of subplot 9. The steel soil cores are both 7.5cm diameter by 10 cm deep and are collected from the substrate surface (below foliage litter). The soil samples are used to measure soil pH, total carbon (%), total nitrogen (%), total phosphorus (mg/kg), electrical conductivity (µS/cm), field bulk density, gravimetric and volumetric water (%) and moisture content (%). Samples are cool stored until ready for laboratory analysis. Where peat soils are present the von Post Index of peat degradation is undertaken.

(c) Foliage: Foliage samples are taken from vegetation in full sun. The priority species are mānuka (*Leptospermum scoparium*), purei (*Carex secta*), tangle fern (*Gleichenia dicarpa*), harakeke (*Phormium tenax*), raupō (*Typha orientalis*) or the dominant plant species in the canopy of the plot. Approximately 5g are collected from the tips of healthy, undamaged leaves, all flowering and woody parts discarded. The foliage sample is used to measure total carbon (%), total nitrogen (%) and total phosphorus (%). Samples are stored in paper bags and air-dried to avoid fungal growth.

2.2.7 Additional information

During the wetland visit, additional recordings with notes are made of (a) native fauna, (b) threatened species, (c) broad trends in hydrology, weeds, grazing or other pressures, and (d) other observations, including the presence of weirs, bunds, jetties, tracks, stock crossings, amenity planting, etc.

2.3 Analyses

Plant species were named according to the Manaaki Whenua Landcare Research Biota of New Zealand database (https://biotanz.landcareresearch.co.nz/). For some genera (e.g. *Carex, Juncus, Isolepis*) identification to species level is difficult in the absence of fertile material. The pest plant pampas are treated as a single taxon unit combining records for *Cortaderia, C. selloana* and *C. jubata*. Species richness estimates included taxa identified to species-level and *Cortaderia*. Taxa identified to genus (72) or family (1) level were excluded. Taxa recorded to species level (including *Cortaderia*) represent 88% of taxa recorded and 99.4% of plant cover.

All statistical analyses were conducted using the R software for statistical computing version 4.3.3 (R 2022). To describe the total number of species recorded in the wetlands TBMP, all species recorded inside the 15 x 15m plots (which includes all species in its sub-plots) were included. All other measures of alpha diversity were estimated from the 10 x 10m sub-plot. Species cover data (%) recorded in three height tiers (<0.3m, >0.3 – 2m, >2m) in the 10 x 10m sub-plot was used as a measure of biomass. Cover data was summed across height tiers to estimate biomass per species per plot, similar to the method used by Holdaway et al (2017). Summed cover data was used as an absolute measure (1 – 300%) of biomass and as a relative measure (1 – 100%) of biomass (i.e. summed cover per species as a percentage of summed cover for all species recorded in the 10 x 10m sub-plot). In all cases, cover data were square root transformed to reduce the effect of outliers.

Models of species richness used a generalised linear mixed effects model with poisson errors. Models of other alpha diversity metrics used linear mixed effects model assuming gaussian error distribution. Absolute cover was square root transformed and modelled using a linear mixed effects model assuming gaussian error distribution, as was data from the four indices (WCI, WPI, WEI and PI). Relative cover was modelled using a generalised linear mixed effects model with binomial errors. Generalised linear mixed effects models and linear mixed effects models were analysed using the packages lme4 and glmmTMB in R (Bates et al 2015, Brookes et al 2025), with plot as a random effect. Significance of fixed effects and their interactions was tested using likelihood ratio tests using the chi-squared distribution.

2.3.1 Alpha diversity

Measures of alpha diversity were calculated using the *vegan* package (Oksanen et al 2022) in R. Species richness describes the number of unique species present.

Shannon Index (H’) quantifies both richness and evenness and ranges from 0 to Infinity. Higher values indicate higher diversity with more evenly distributed abundances. Lower values indicate lower diversity and/or greater dominance by fewer species. Shannon is more sensitive to rare species than Simpson index.

Simpson’s Dominance Index (D) describes the probability that two randomly selected individuals will belong to different species, with values ranging from 0 to 1. Values closer to 1 indicate higher diversity with even distribution, values closer to 0 indicate lower diversity with stronger dominance. Simpson's D is less sensitive to rare species than Shannon.

Inverse Simpsons index (1/D) is the inverse of Simpsons index (D) and ranges from 1 to species richness (maximum diversity). Inverse Simpsons indicates the number of the most abundant species in a community, when one species dominates 1/D = 1, if all species are equally abundant 1/D = SR. Inverse Simpsons can be useful for comparing communities with different richness.

Pielou's evenness index (J) describes the ratio of observed Shannon diversity to maximum possible diversity, and ranges from 0 to 1. Values closer to 1 indicate communities where abundance is more evenly distributed across species. Values closer to 0 indicate strong dominance by one or a few species. Similar to Shannon, Pielou's evenness can be sensitive to rare species.

2.3.2 Non-metric multidimensional scaling (NMDS) and Procrustes analysis

NMDS using the metaMDS function in the package *vegan* (Oksanen et al 2022) was used to describe the relationship between plant communities within a rotation using absolute species cover from the 10 x 10m subplot. Bray-Curtis dissimilarity was used to generate the distance matrix between plots. The number of dimensions (axis) was selected to keep stress levels ≤0.15. Procrustes analyses were used to examine changes in plant communities over time and were performed using the protest function (Jackson 1995) implemented in vegan to examine the 'rotation' required to map NMDS ordinations from rotation 3 (2019-2022) onto rotation 1 (2009-2013, Peres-Neto and Jackson 2001). Procrustes residuals were used to identify plots with greater than expected change in composition.

2.3.3 Indicators and functional groups

Functional groupings of plants were used to better understand ecological processes or pressures.

(a) Wetland Indicator Status and the modified Prevalence Index (PI_{mod})

Wetland hydrology or water quantity, a compulsory value to monitor in the NPS-FM, is not currently monitored in the TBMP wetland plot protocol. The Prevalence Index has been proposed as a potential tool to monitor the hydrological regime at a plot using the community of plant species abundances and their known wetland indicator status (Clarkson et al 2014, Clarkson et al 2021). The use of the Prevalence Index has been developed to support the delineation of wetlands as part of the NPS-FM (Clarkson 2013, Clarkson et al 2021, MfE 2022), but this tool has not been developed further for hydrological monitoring. Here we test a modified Prevalence Index (PI_{mod}) for hydrological monitoring using existing TBMP data.

There are five wetland indicator status categories based on the extent to which species are hydrophytes, with hydrophytes defined as aquatic and wetland plants capable of growing in soils that are often or constantly saturated with water during the growing season. Obligate species (OBL) are almost always hydrophytes; facultative wetland species (FACW) are usually hydrophytes but sometimes found in non-wetland settings; facultative species (FAC) occur as hydrophytes or non-hydrophytes; facultative upland species (FACU) are occasionally wetland species but more typically occur in non-wetland (upland) settings; and upland species (UPL) are rarely hydrophytes and almost always found in non-wetland (upland) settings. Hydrophytes include the four categories obligate, facultative wetland, facultative and facultative upland.

The Prevalence Index (PI) is calculated by taking the wetland indicator status (coded as an ordinal variable, 1 = OBL, 2 = FACW, 3 = FAC, 4 = FACU, 5 = UPL) and calculating the weighted mean of these indicator values for all species in a community (the wetland plot), where the weighting is based on species cover (Clarkson et al 2018). Mean values close to 1 indicate a high % cover of hydrophytic plants and a 'wet' plot, mean values close to 5 indicate a high % cover of hydrophobic plant species and a 'dry' plot. Sites with a Prevalence Index values ≥ 3 are not considered wetlands.

The Prevalence Index was developed in the USA where several different plot protocols are in use (Clarkson 2013). Two alternative plot methods in use in Aotearoa New Zealand are (a) the wetland delineation protocol (MfE 2022, Clarkson 2018) which sums % cover values for all vascular plants (including Sphagnum) measured in three strata, herbaceous plants from a 2 x 2m plot, saplings and shrubs from a circular 5m radius plot, and trees (> 10 cm DBH, diameter at breast height or 1.35m) from a circular 10m radius plot, and (b) the Bay of Plenty wetland plot protocol (Clarkson et al 2014) which collects the (maximum) % species cover from a 5 x 5m plot irrespective of height or tier. Both include Sphagnum moss and plots are located within a single vegetation type.

In this report we examine the potential to use a modified Prevalence Index (PI_{mod}) using existing % species cover data collected using the TBMP plot protocol. In the TBMP protocol we collect % cover data for all vascular plants from a 10 x 10m plot at three height tiers (0 – 0.3m, ≥0.3 – 2m, ≥2m). To calculate the PI_{mod} we use the maximum cover for each species from the three height tiers; this most closely aligns with the maximum cover value per strata used by Clarkson (2018) in the wetland delineation method, and the maximum cover value used for the Bay of Plenty wetland plot protocol (Clarkson et al 2014). The random plot location used in the TBMP means that plots can cross more than one vegetation type. The main impact of the different protocols is to vary the area over which % species cover is estimated (Table 3).

Table 3. Plot areas (m^2) used to estimate % species cover for calculation of the Prevalence Index and modified Prevalence Index (PI_{mod}).

Protocol	Plot method	Area (m^2)
Wetland delineation	Herbaceous strata: 2 x 2m	4
Wetland delineation	Saplings/shrubs strata: 5m radius circle	78.5
Wetland delineation	Trees (> 10cm DBH) strata: 10m radius circle	314.2
Bay of Plenty	5 x 5m plot	25
TBMP	10 x 10m plot	100

Plant species occurring in the TBMP that are not on the Clarkson et al 2021 list were assigned a wetland indicator status. Wetland status was assigned by checking the Wetland plant database of the United States Department of Agriculture (https://plants.usda.gov/), by assigning indicator status based on our understanding of the species or by assuming an upland status for non-wetland plants. New indicator ratings were submitted to the Manaaki Whenua Landcare Research wetland database for checking. Of the 599 taxa recorded over the 15 years of the TBMP, 391 are assigned a wetland status based on Clarkson et al 2021 or personal communication with Beverley Clarkson, 28 taxa were in the USDA database, 77 received a default upland status and we assigned a wetland status to 30 taxa. Wetland indicator status assigned to species not in Clarkson et al 2021 are preliminary and we welcome feedback; the wetland indicator status of plant species is listed in Appendix 1. There were 73 taxa with no wetland indicator status, these were either taxa identified to genus only or hybrids for which it was difficult to assign wetland status. The total cover of uncategorised taxa represented less than 0.02 % of total plant cover and these taxa were omitted from the analysis.

Of the 526 taxa assigned a wetland indicator status rating, there were 83 obligate wetland (13.9%), 81 facultative wetland (13.5%), 76 facultative (12.7%), 154 facultative upland (25.7%) and 132 upland (23%) species recorded. Upland and facultative upland plants recorded in plots will partly be epiphytic plants, overhanging foliage of species including vines rooted in adjacent dryland slopes, seedlings on root-bases or areas of higher ground, or where the pre-determined plots extended onto dry ground (within the 20% tolerance of the protocol).

(b) Native, exotic and weed

Native or indigenous species are those that occur naturally in New Zealand. Exotic species are those whose presence in New Zealand is outside of their natural geographic range. Weeds are species considered capable of having serious adverse effect on the environment or people. Species were categorised as native or exotic according to the National Vegetation System (NVS) database hosted by Manaaki Whenua Landcare Research, and as pest plants (Appendix 2) if they appeared on either the Department of Conservation's published list of environmental weeds (MacAlpine and Howell 2024), and/or Auckland Council's Regional Pest Management Plan (2020).

(c) Plant conservation status

The conservation status of all known New Zealand indigenous vascular plant species is assessed using the New Zealand Threat Classification System for national (de Lange et al 2024) and regional (Simpkins et al 2022) conservation status. Categories are Threatened (Nationally/Regionally Critical, Nationally/Regionally Endangered, Nationally/Regionally Vulnerable), At Risk (Declining, Naturally Uncommon) or Data Deficient (Appendix 3).

(d) Nutrient enrichment indicators

Structural and biogeochemical indicators can be used to detect nutrient enrichment of a wetland. Structural indicators include an increase in biomass of indicator species such as raupō (*Typha orientalis*) that shows a prolific growth response to nutrient enrichment, and a corresponding decline in plant community diversity (US EPA 2002; Sorrel 2012). Plant community responses can show a time-lag of several years following exposure to enrichment, and similar plant community changes can result from many different environmental pressures (US EPA 2002). To attribute some causation to nutrient enrichment, physiochemical data on nutrient levels in wetland soil and plant foliage are required, and ideally some evidence of potential nutrient sources.

Nitrogen and phosphorus are the two main growth-limiting nutrients for plants and are common in enriched run-off from farmed and urban land. Together with carbon, these three nutrients are measured in soil and foliage samples and can be used in combination as indicators of nutrient enrichment. Nitrogen and phosphorus are generally required in a ratio of 10:1 (i.e. plants need ten times as much nitrogen as phosphorus, Sorrel 2012), and mean soil N:P in swamps was found to be 9.1 (Clarkson et al 2004). In eutrophic wetlands, where plants are growing faster, nitrogen tends to be the more limiting nutrient. In more oligotrophic wetlands, phosphorus is more likely to be limiting (Sorrel, 2012).

Leaf tissue nitrogen and phosphorus will both respond to enrichment, especially where those nutrients are limiting. Together with increasing leaf nitrogen, a decreasing C:N ratio will indicate whether plants are assimilating more nitrogen. Similarly, phosphorus enrichment will show in foliage and a decreasing C:P ratio (US EPA 2002). The N:P ratio of foliage has been used to indicate nutrient limitation in wetlands (Clarkson et al 2004, Burge et al 2019). It is broadly hypothesised that vegetation tissue N:P ratios of <14 have been used to indicate N-limitation, >16 to indicate P-limitation, and 14-16 to indicate co-limitation but these boundaries will shift with wetland context. This information helps to identify if wetlands are more at risk of nitrogen or phosphorus enrichment.

2.3.4 Land cover and ecosystem classification

The New Zealand Land Cover Database (LCDB, Landcare Research Ltd, 2020) was used to describe the surrounding land cover context of each wetland plot. LCDB is a nationally consistent classification derived from remote sensing and refined overtime to maintain backwards compatibility. This 2018/19 time stamp (LCDBv5) was intersected with a 1000m radius buffer around each wetland (P corner) to determine dominant land cover.

Dominance was defined as any land cover class comprising ≥50% of the buffer area. Land cover classes were grouped into medium land cover categories following the LAWA (Land, Air, Water Aotearoa, www.lawa.org.nz) framework; Indigenous (Indigenous forest, Indigenous scrub/shrubland), Exotic (Exotic forest, Exotic scrub/shrubland), Rural (Exotic grassland, Cropping/horticulture), Urban (Urban area, Artificial bare surfaces), Water (Water bodies), Other (all other classes) and Mixed (where no land cover class ≥ 50% of the 1000m buffer area).

Wetland ecosystem types were classified using the Current Extent Ecosystem layer, which maps remaining indigenous ecosystems across Auckland. Wetland plot locations were intersected with this layer to classify wetlands according to Singers et al (2017) classification framework. This provides a complementary and nationally recognised ecosystem typology that supports reporting. Field-based wetland types, described earlier, were assigned using the Johnson and Gerbeaux (2004) classification based on ecological attributes observed during site assessments.

2.3.5 Data caveats

The TBMP wetland plot network is designed to describe the dominant plant composition and structure and broad changes over time. It is not designed to capture uncommon or highly localised species. Changes at specific plots may act as a trigger for further investigation but cannot be used to draw conclusions about a particular wetland, as the plot may not be representative of the whole wetland. However, the wetland condition indices do apply to the whole wetland for most sites and could be used to assess change.

3 Results and Discussion

3.1 Characterising the TBMP wetland plot network

The 189 plots that form the wetland plot network were established using a spatially stratified systematic site selection process. This site selection process resulted in a wetland plot network with marginally more wetlands on private land (53% or 101) than public land (47% or 88 plots). Public lands were a mixture of Auckland Council regional parks and local reserves, Watercare and Department of Conservation land. Wetland plots on private land include four plots on private forestry land. Most wetland plots were in landscapes dominated by rural land cover, with fewer plots in areas dominated by indigenous, urban, exotic and other land cover types (Table 4). Dominant land cover was determined using LCDB 2018 within a 1000m buffer around each plot, grouped according to LAWA medium land cover categories.

The size of a wetland will influence its sensitivity to adjacent land cover and other pressures. Mean wetland area (ha) was 7.4 ± 2.9 ha. There was a large range in wetland area from 0.1 ha to 490 ha, but most wetlands were small, 67 plots were in wetlands with an extent <1.0 ha, and five plots in wetlands that were 0.1 ha in extent (the smallest wetland size included in the TBMP). Only 14 wetland sites were larger than 10ha and only three wetlands larger than 100ha. These were the Marie Neverman wetland (122ha), Bethells (155 ha) and Whatipu (490 ha). Wetland area was smallest in landscapes dominated by exotic forest/scrub, rural and urban land cover types and larger in areas dominated by indigenous forest/scrub (Table 4).

Table 4. Number, % and mean area (ha) of wetlands in each dominant land cover class.

Dominant land cover (LCDB 2018)	Number of plots	% of plots	Wetland area (ha)	
			mean	s.e.
Rural	115	60.8	4.0	1.2
Indigenous forest scrub	29	15.3	9.4	5.4
Urban	26	13.8	2.6	0.8
Exotic forest/scrub	13	6.9	3.3	1.5
Other	1	0.5	490.0	
Water	1	0.5	3.2	
Mixed	4	2.1	1.4	0.6

The majority of wetland plots in the TBMP meet the definitions of natural inland wetland defined according to the NPS-FM. Four wetland plots were in the coastal marine area and seven plots had >50% exotic pasture species but only one was in grazed pasture and could potentially pass the Pasture Exclusion Test (MfE 2022). Wetlands with more than 50 per cent cover of exotic pasture species (sum of herb, shrub and tree tiers) within grazed pasture are excluded from the NPS-FM provisions unless they are habitat for threatened species. It is not possible to definitively identify wetland plots that would pass the pasture exclusion test (MfE 2022) as the vegetation plot methodologies differ. Further investigation is needed to determine if any plots are associated with wetlands that meet the NPS-FM definition of constructed wetland. Two plots are associated with constructed wetlands but also meet the criteria for restoration or offsetting of existing or former natural wetlands. Many urban wetlands will be influenced by stormwater infrastructure to some degree but will not meet the NPS-FM definition of constructed wetland.

There were 92 plots inside and 91 (of 189) plots outside of Terrestrial SEA, providing sufficient plots to track and compare changes in wetlands within and outside of Terrestrial SEA. It is important to note that these data would not provide a test for the effectiveness of Terrestrial SEA provisions. The TBMP was not designed to assess impacts of SEA on wetlands, consequently, the distribution of wetland plots across SEAs is neither complete nor balanced and cannot be used to replace an analysis of resource consent data.

Twenty-seven plots (14%) were connected with wetlands identified in the AUP Wetland Management Area overlay (WMA). Similarly to the SEA, while it would be possible to track changes in the WMA-connected wetlands as a sub-group, this data is not designed to assess the effectiveness of WMA protections.

3.2 Classification of wetlands in the TBMP

Most wetlands in the TBMP are palustrine (181 of 189 wetlands sampled) i.e. freshwater systems fed by rain, groundwater or surface water but not directly associated with estuaries, lakes or rivers. As a result, the hydrology and water quality of these wetlands is sensitive to adjacent land-use and changes to rainfall patterns induced by climate change. In addition, four are estuarine, three lacustrine and one riverine.

The two main classes (as identified by the field team based on Johnson and Gerbeaux 2004) of wetlands were swamps (151 of 189) and marshes (20 of 189); there were also six ephemeral wetlands, four seepage wetlands, four fens, two saltmarsh, one shallow wetland and one bog. There are plots at three of the largest wetlands in Tāmaki Makaurau broadly classed as swamps, Whatipu (490 ha), Te Henga (Bethells, 155 ha) and Marie Neverman Reserve (122 ha).

Swamps (147 of 189) have moderate water flow and fluctuation, and the water table is permanently or periodically above the ground surface. In contrast, marshes (20 of 189) have better drainage than swamps, a lower water table but also greater fluctuation in water levels, more mineral substrate and are more acidic. Ephemeral wetlands (6 of 189) are characterised by pronounced fluctuation in water levels, often completely drying out in summer or dry years. Seepages (4 of 189) can vary in their substrate, pH and nutrient status, but almost always form on slopes with a steady flow of ground or surface water. They are usually small and localised but may intergrade with bogs, fens, marshes or swamps. Fens (4 of 189) have a predominately peat substrate and fairly constant water table at or just below the peat surface and slow water flow. They have low to moderate acidity and are oligotrophic to mesotrophic. Fens may grade downslope into swamps. Saltmarsh wetlands occur in estuarine and palustrine systems where the water source is from rain, ground and surface water and adjacent saline estuary water. The only bog in the TBMP wetland plot network formed in a basin of a palustrine system with a rushland vegetation structure. Shallow wetlands are characterised by the presence of standing or open water, usually less than a few metres deep. The nutrient content and water chemistry of these wetlands is more defined by the water and its source, than the substrate (Johnson & Gerbeaux 2004).

The dominance of swamps and marshes across the palustrine hydrosystem in the TBMP wetland network, reflects a similar pattern observed from wetland mapping of Tāmaki Makaurau (Lawrence & Bishop, 2017). The TBMP wetland plot network best describes the state and trends in palustrine swamps and marshes.

Ecosystem classification using Singers et al. (2017) shows that most TBMP wetlands were Raupō reedland (WL19, 81 of 189), Exotic wetlands (EW, 37 of 189) and Machaerina sedgeland (WL11, 20 of 189), with fifteen other wetland and non-wetland ecosystems represented (Table 5). Nineteen wetlands were classified using non-wetland categories (e.g. Mānuka, kānuka scrub, VS3). One of the limitations of the Singers et al. (2017) classification system it its reliance on canopy vegetation which can underrepresent or misclassify forested wetlands and wetlands dominated by exotic species. The seven woody ecosystem categories (SA1.2, PL, WF5, EF, WF8, WF4, VS2 and WF11) representing fifteen wetland sites are combined into a single 'Mixed Forest' (MF) category in future analyses.

Table 5. Ecosystem types (Singers et al 2017) represented in the TBMP wetland plot network. The lower seven ecosystem categories (PL to WF11) are combined into a single 'Mixed Forest' (MF) category in future analyses.

Ecosystem	Code	Number of plots
Raupō reedland	WL19	81
Exotic wetland	EW	37
Machaerina sedgeland	WL11	20
Flaxland	WL18	7
Mānuka, tangle fern, scrub, fernland	WL12	7
Mānuka, kānuka scrub	VS3	6
Saltmarsh - Sea rush oioi	SA1.3	6
Broadleaved scrub/forest	VS5	4
Oioi restiad rushland/reedland	WL10	4
Dune plains	DN5	3
Mangrove forest and scrub	SA1.2	3
Planted vegetation	PL	3
Dune forest	WF5	2
Exotic forest	EF	2
Kahikatea, pukatea forest	WF8	2
Coastal broadleaved forest	WF4	1
Kānuka scrub/forest	VS2	1
Kauri, podocarp, broadleaved forest	WF11	1

There was poor correspondence between the two wetland classification systems. For example, the swamp wetland class included 20 different ecosystems. In addition, NMDS analyses showed only a weak separation of plots by wetland class (Johnson & Gerbeaux 2004, Figure 3a) or ecosystem (Singers et al 2017, Figure 3b). For wetland class, poor separation of plots may result from distinctiveness of the 10 x 10m subplot vegetation from the overall wetland class or from misapplication of the Johnson and Gerbeaux (2004) system in the field which can be complex and require prior knowledge of a wetland. For the ecosystem classifications (Singers et al 2017), there can be considerable overlap in plant composition between wetlands and classifications, and plot locations are pre-determined and may include more than one vegetation type. In contrast, classifications from the mapping layer are based on the location of the plot 'P' corner. Classifications can be difficult to apply in wetlands dominated by *Carex* or exotic species and where there is a forested canopy. Further work is required to verify both classification systems using field-based and geospatial tools.

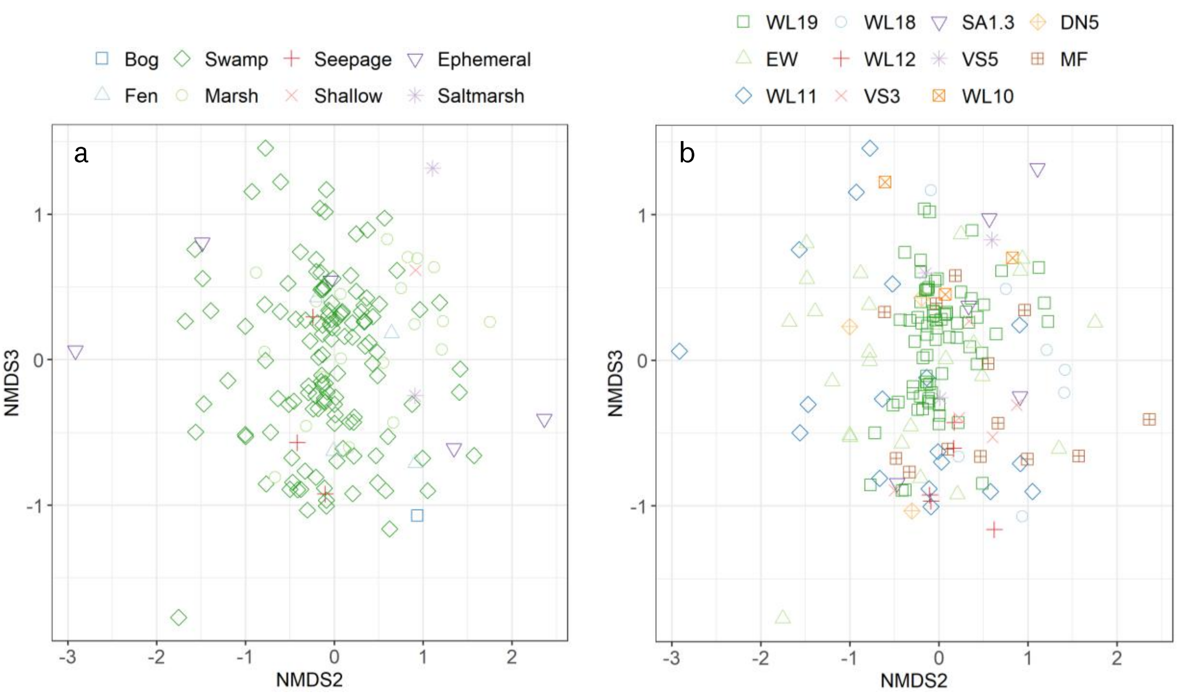

Figure 3. NMDS analysis of species biomass (absolute % species cover) per plot in rotation 3 . The first dimension (axis NMDS1, not shown) separated out saltmarsh communities. The second and third dimensions (NMDS2 and NMDS3) are illustrated: (a) Plots are coloured by wetland class (Johnson & Gerbeaux 2004), and (b) Plots coloured by ecosystem type (Singers et al 2017).

3.3 Wetland plant community

3.3.1 Overview

Across 15 years of wetland monitoring 599 taxa have been recorded, with 530 identified to species level. Of these 268 are indigenous vascular plant species.

In rotation 3 (2020-2024), 200 indigenous vascular plant species were recorded. This is 25.3% of the 792 indigenous vascular plant species known to occur in Tāmaki Makaurau (Simpkins et al 2025), highlighting the valuable role that wetlands play in supporting plant biodiversity. Of those 200 indigenous plants, 43 of them (21.5%) are considered regionally or nationally Threatened, At-Risk or Data-Deficient according to the New Zealand Threat Classification System (Simpkins et al 2022, de Lange et al 2024), indicating the vulnerability of these plants. Twenty-seven of the 43 Threatened, At-Risk or Data-Deficient species are wetland obligates, requiring wet conditions to survive, or facultative wetland species, that are typically hydrophilic and only occasionally found in non-wetland conditions. This dominance of hydrophilic species (63%) highlights the pressure placed on wetland plants by changes in wetland hydrology through drainage, abstraction, drought and dryland plant invasion changing the wetland hydrology.

Indigenous species composed barely half of all plant species. Of the 391 species recorded in the 3rd rotation 200 (51%) are indigenous and 189 are exotic, or plants whose presence in New Zealand is outside of their natural range (the biostatus of two species is uncertain). Within exotic species, 99 (25.3%) are exotic but not weeds (as defined by MacAlpine and Howell 2024 or the Auckland RPMP), while 82 species (21%) are weeds, or species considered capable of serious adverse effects on the environment or people. This result mirrors an eDNA study of New Zealand wetlands that found ≥50% of all species (flora and fauna) were exotic (Bird et al 2024). Wetlands ecosystems, dominated as they are by herbaceous plants with a high turnover in biomass, are especially vulnerable to exotic species that have a greater proportion of herbaceous and annual species than the native flora in New Zealand and have life history traits that provide competitive advantages (Brandt et al 2020).

Further analyses of the plant community use species biomass data from the 10 x 10m subplot.

3.3.2 Alpha diversity

Indigenous plant diversity showed a small increase in species richness ($\chi^2 = 8.1$, $P < 0.05$) and a large decline in evenness ($\chi^2 = 14.8$, $P < 0.001$), indicating increasing disparity in the distribution of biomass (% cover) across species, across the three rotations (Figure 4). The number of dominant species remained constant at around 2.8 ± 0.08 dominant species per plot (Inverse Simpsons). This combination would support a pattern where dominant indigenous species are becoming more dominant. There was no change in any alpha diversity metrics for exotic species across the three rotations.

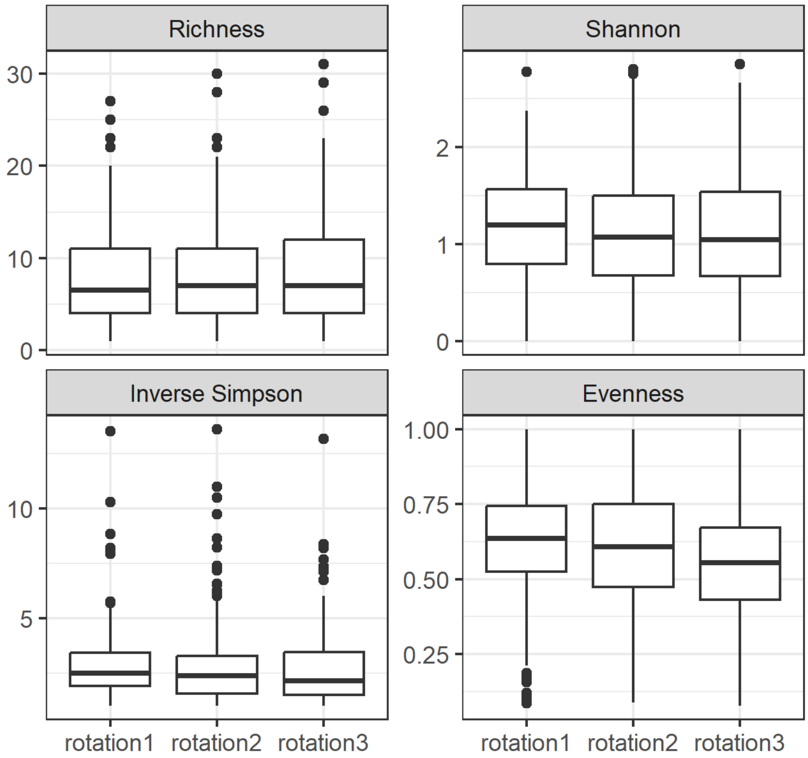

Figure 4. Alpha diversity metrics using indigenous species biomass data (absolute % species cover) in each rotation.

Wetland plots supported similar numbers of indigenous and exotic species, but there were fewer indigenous dominants (2.7 species per plot) than exotic dominants (3.3 species per plot, Inverse Simpson, $\chi^2 = 12.6$, $P < 0.001$), and the indigenous community was less diverse (Shannon, $\chi^2 = 8.1$, $P < 0.01$) and less even (Pielou, $\chi^2 = 44.4$, $P < 0.001$) than the exotic plant community. Communities that are more diverse, including with a more even distribution of individuals across species, typically support higher levels of ecosystem functions and are more resilient to perturbations (Hong et al 2021).

3.3.2 Community composition

NMDS was used to look for patterns in indigenous plant communities in rotation 3 using species biomass data (absolute % species cover), as with the exception of Exotic wetland (EW), wetland ecosystem classifications are based on indigenous species only (Singers et al 2017). Three dimensions were required to reduce the stress level of the NMDS < 0.15. The first axis, NMDS1 separated out communities adapted to saline conditions. These were saltmarsh communities dominated by or containing sea rush (JUNKRA, *Juncus krausii* subsp. *australiensis*), together with less abundant batchelors buttons (*Cotula coronopfolia*) and *Trichoglin striata*. These species all tolerate muddy and saline conditions typical of coastal margins, estuaries and brackish waters. Where sea rush was present but not dominant, the weed saltwater paspalum (*Paspalum vaginatum*) was the dominant species, together with other exotic species particularly blackberry *(Rubus fructicosa*) which was presumably rooted outside the plot in non-saline soil.

The next two axis (NMDS axes 2 and 3) showed only a weak separation of plots by ecosystem classification (Figure 5a). The 20 most abundant indigenous species are illustrated in ordination space (Figure 5b). Species at the centre of the ordination are the most widespread, this includes raupō (TYPORI, *Typha orientalis*), pōhuehue (MUECOM, *Muelenbeckia complexa*), *Persicaria decipiens* (PERDEC), swamp sedge (CARVIR, *Carex virgata*) and *Carex lessonii* (CARLES).

As the most common wetland ecosystem, most Raupō reedland (WL19) wetland plots are clustered together near the centre of the ordination space, around raupō (TYPORI) which often dominates this ecosystem. Co-occurring and abundant plant associates with raupō include swamp millet (ISAGLO, *Isachne globosa*), jointed twig rush (MACATC, *Machaerina articulata*), lake clubrush (SCHTAB, *Schoenoplectus tabernaemontani*) and less commonly kuta (ELESPH, *Eleocharis sphacelata*) and purua grass (BOLFLU, *Bolboschoenus fluviatilis*). *P. decipiens* (PERDEC), *Isolepsis prolifera* (ISOPRO) and *M. complexa* (MUECOM) were widespread though less abundant in Raupō reedland.

Machaerina sedgeland (WL11) was distributed across the top of the ordination space and shared many species with Mānuka, tanglefern, scrub, fernland (WL12) and Mixed forest (MF) wetland plots. Machaerina sedgeland (WL11) plots were variable in their plant composition, but common dominant species included jointed twig rush (MACATC), *M. rubignosa* (MACRUB), *M. juncea* (MACJUN), *E. acuta* (ELEACU), swamp sedge (CARVIR), purei (CARSEC, *Carex secta*), *Carex germinata* (CARGEM), I. prolifera (ISOPRO) and mānuka (LEPSCO, *Leptospermum scoparium*).

The indigenous species component of Exotic wetlands (EW) have a broad distribution in ordination space indicating highly variable composition in these plots.

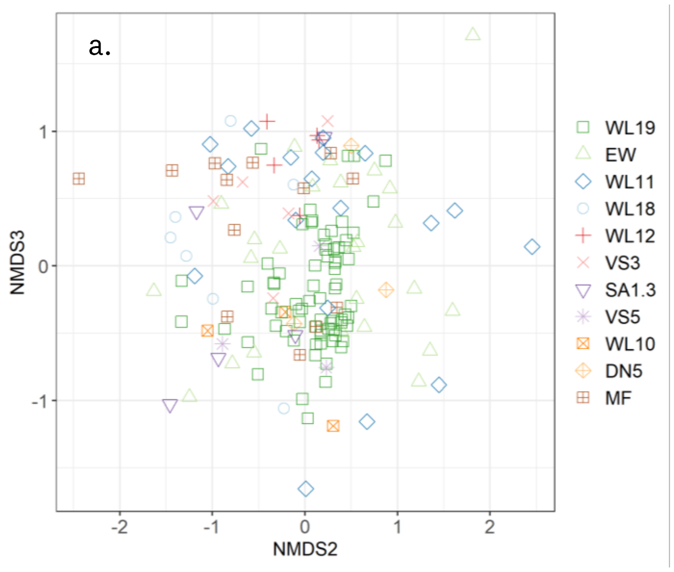

Figure 5. NMDS analysis of wetland plot communities (absolute % species cover) in rotation 3 . The first dimension (axis NMDS1, not shown) separated out saltmarsh communities. The second and third dimensions (NMDS2 and NMDS3) are illustrated: (a) Plots coloured by ecosystem type, and (b) The 20 most abundant species displayed using their 6 letter species code.

Procrustes analyses (Procrustes m^2 = 0.53, correlation 0.62, P = 0.001 on 999 permutations) was conducted on the indigenous vegetation of 154 plots measured in both rotation 1 (2010-2014) and rotation 3 (2020-2024) to look for changes in plant communities over time (Figure 6). One plot was dropped from the analyses as an outlier; the vegetation in this plot (Pukaki crater) showed a transition from freshwater wetland dominated by *Isolepsis prolifera* in rotation 1 to saltmarsh dominated by sea rush (JUNKRA) in rotation 3 . The Procrustes statistic (m^2) of 0.53 indicates there were substantial changes in plant community composition and structure, but not a major reorganisation of the communities (Peres-Neto & Jackson, 2001).

For each plot, its location in ordination space in rotation 1 is shown as a yellow circle, and for rotation 3 as an arrowhead. The direction of the arrow indicates the direction of change in the plant community in ordination space from rotation 1 to rotation 3 . The length of the arrow represents the level of change in that plant community. The outward radiation of arrows indicates a consistent pattern of plant communities in rotation 3 shifting away from common plant communities in rotation 1. Plots that showed the largest changes (residuals > 1.0, plots M15B, H30, N8, O26, O34, H29, M12, P28B, J12) were explored further.

Five of the plots showing large changes between rotation 1 and 3 were already dominated by exotic species in rotation 1, but weed biomass increased in rotation 3, especially of saltwater paspalum (PASVAG), reed sweet grass (GLYMAX), kikuyu grass (CENCLA) and mercer grass (PASDIS). There was also evidence these plots were becoming drier, with an increase in the biomass of less hydrophytic plants including tōtara (PODTOT), radiata pine (PINRAD), and other more upland herbs including German ivy (DELODO), hawksbeard (CRECAP), ragwort (JACVUL) and perennial ryegrass (LOLPER). In one of the plots dominated by exotic species in rotation 1, dominance by the invasive species reed sweetgrass (*Glyceria maxima*, GLYMAX) decreased between rotation 1 and rotation 3, accompanied by an increase in species richness from 2 to 20 species. All new species however, were exotic and many were facultative or facultative upland species.

The other four plots showing a large change in composition between rotations 1 and 3 were increasingly dominated by the indigenous species oioi (APOSIM), sea rush (JUNKRA) and raupō (TYPORI). In the sea rush (JUNKRA) dominated plot there was also an increase in the cover of the invasive saltwater paspalum (PASVAG).

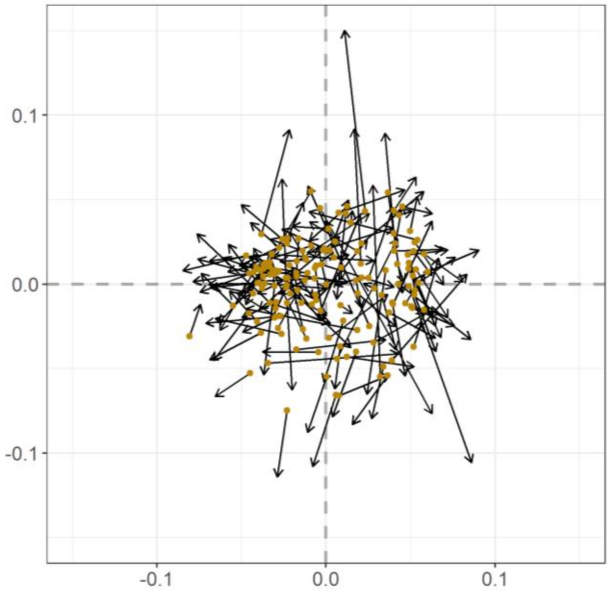

Figure 6. Procrustes analyses examining change in plant communities between rotation 1 (2009-2013, yellow circles) and rotation 3 (2019-2022, arrow heads) described by NMDS ordination, for all plots recorded in both rotations (n= 154). The species compositions showed considerable turnover between the two measurement periods (correlation = 0.69, m2 = 0.53, P<0.001 based on 999 permutations). Length of arrows shows the amount of movement required by each plot to align the two NMDS ordinations.

3.3.4 Distribution of biomass across species

Across all plots in rotation 3, 50% of plant biomass (relative % species cover) is composed of 7 species and >90% of plant biomass is composed of 47 species. The remaining 10% of plant biomass is composed of 301 different species (note the species richness is lower in the 10x0 m plot used for biomass estimation than in the 15x15 m plot used for overall species richness). The most abundant species is the native raupō composing almost 20% of biomass across all 163 plots. Raupō occurred in 89 (of 163) plots and in seven of eight wetland classes (raupō was not recorded in shallow water). This highlights one of the difficulties of using a wetland-scale classification, that it may not represent the plot composition, for example, nutrient-responsive raupō would not be expected in a nutrient-poor bog. The most commonly occurring species was lotus (*Lotus pedunculatus*); this exotic species was recorded in 118 (of 163) wetland plots. Together with the grass weed Yorkshire fog (*Holcus lanatus*) these were the only three species occurring in more than half of wetland plots.

Raupō was also the species most likely to dominate the plant biomass at a plot level, forming >50% of the plant biomass in 30 (of 163) plots in rotation 3 (Figure 7). The native grass swamp millet (*Isachne globosa*) and the weed mercer grass (*Paspalum distichum*) also tended to dominate the biomass where they occurred, forming > 50% of plant biomass in 11 (of 163) plots. Purua grass (*Bolboschoenus fluviatilis*) formed >50% of seven (of 163) plots and the weed grass kikuyu (*Cenchrus clandestinus*) forming > 50% of plant biomass in three (of 163) plots.

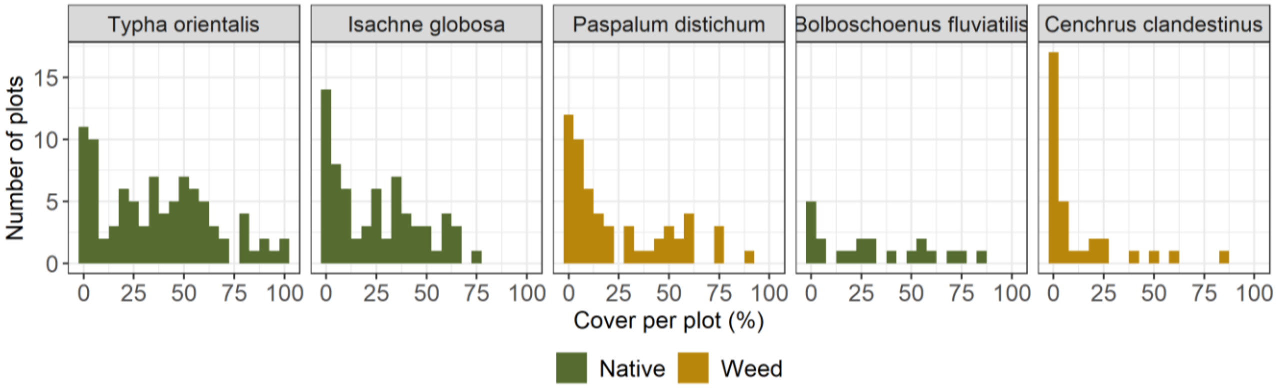

Figure 7. The frequency-abundance distribution (relative % species cover) for the five species that most frequently exceed 50% cover within a plot.

Although lotus was the most widespread species, it generally composed <20% of plant biomass in a plot (Figure 8). Several other species show a similar pattern of being widespread but not becoming highly dominant at a plot level.

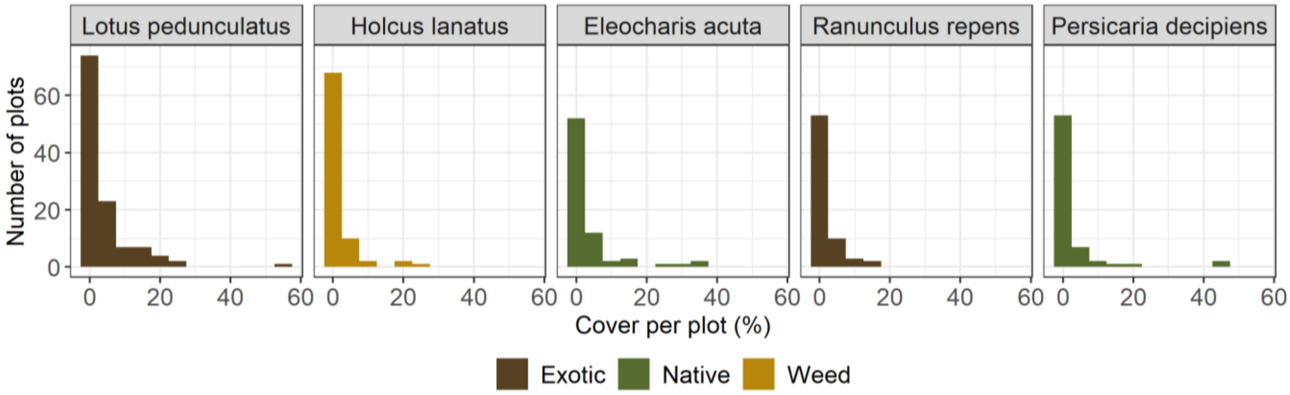

Figure 8. The frequency-abundance distribution (relative % species cover) for species that are widespread but rarely exceed 50% cover within a plot.

Two hundred and seventy-seven species occurred in less than 10 wetland plots, while 108 species occurred in only one plot. These unique species were recorded in 64 (of 163) plots including swamp, marsh, ephemeral and seepage wetlands on a mixture of public and private land and ranging in size from 0.2 to 490 ha. These data illustrate how a few plant species dominate plant biomass, but wetlands of all descriptions support many small, uncommon, or less widely distributed species (Richardson et al 2014).

3.3.5 Plant biomass

In rotation 3, most plant biomass (relative % species cover) was composed of indigenous species (67%), but weeds composed 21% and exotic plants (that are not classed as weeds) composed 9%. Indigenous plant species identified as Threatened and At-risk composed 2.3% of plant biomass.

Mean plant biomass increased significantly across the three rotations (absolute % species cover, Figure 9a) and this increase was observed in indigenous species, weeds and threatened species (relative % species cover, Figure 9b). Exotic species (that are not classed as weeds) decreased in biomass. Native species had both the largest biomass in any rotation and the largest increase in biomass over the 15-year monitoring period.

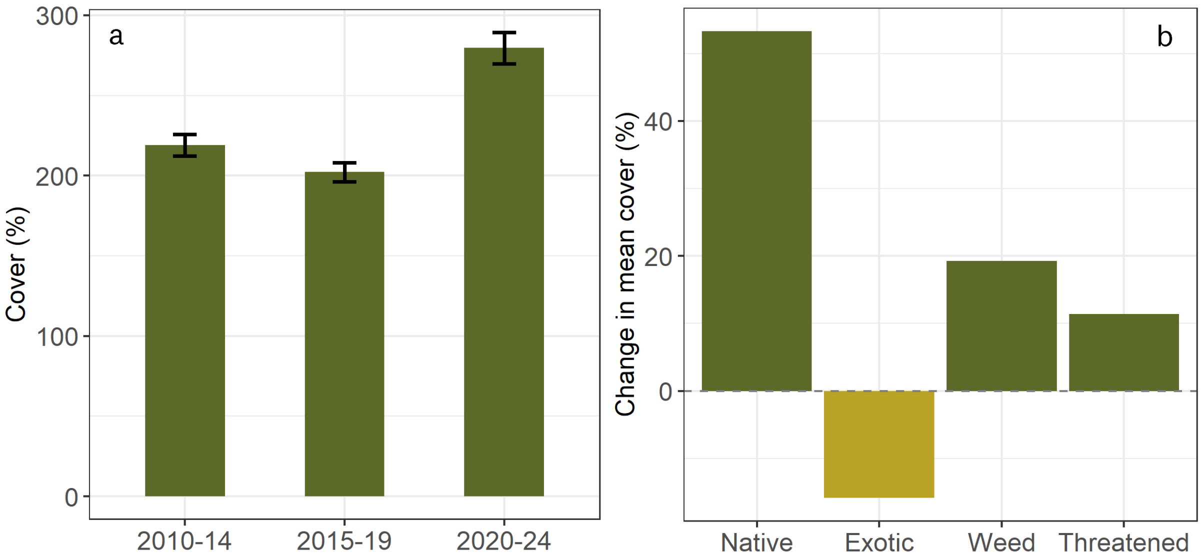

Figure 9. Changes in plant biomass (a) Mean (± s.e) biomass (absolute % species cover) per plot in each rotation (χ^2 = 52.5, P < 0.001), (b) The contribution to change in biomass (relative % species cover) by native plants, exotics (not including weeds), weeds and threatened or at-risk plants.

The net increase in native biomass (relative % species cover) was the result of many small increases and decreases across the 220 indigenous species recorded in the 10 x 10m subplot across the three rotations. A small number of species however, contributed disproportionately either to mean biomass, changes in mean biomass or both (Figure 10a). The three most abundant indigenous species raupō (20.2%), swamp millet (10.3%) and purua grass (4%) together composed 34 % of biomass in rotation 3, compared to 26% in rotation 1, with raupō increasing by 4% and swamp millet and purua grass both increasing by 2% of total plant biomass. As identified in the alpha diversity analyses, these three dominant species were becoming increasingly dominant. All three species are common components of Raupō reedland (WL19). Raupō in particular, grows rapidly in response to nutrient enrichment. Three other indigenous species that increased in biomass (≥ 1% of relative mean cover) were *Bolboschoenus medianus*, *C.geminata* and sea rush.

Indigenous species showing the largest decreases in biomass (≥ 1% of relative % species cover) were sharp spike sedge (*Eleocharis acuta*), kuawa (*Schoenoplectus tabernaemontani*) and rautahi (*Carex lessoniana*), species typical of Machaerina sedgeland (WL11).

Although sea rush has increased in biomass across the region, it has been recorded at fewer plots in each rotation (10, 8, 7 respectively). This suggests that increase in biomass of the salt-tolerant sea rush is a localised response to site-specific coastal morphology or modifications.

Of the 119 exotic species (that are not weeds) recorded in the 10 x 10m subplot, 17 increased in cover, but 44 decreased. No exotic species showed large increases but several decreased by >1% over the 15 years of monitoring including lotus (*Lotus pedunculatus*), soft rush (*Juncus effusus*), willow weed (*Persicaria maculosa*) and creeping buttercup (*Ranunculus repens*). Paspalum (*Paspalum dilatatum*) decreased by > 0.5% biomass (Figure 10b).

Of the 87 weed species recorded in the 10 x 10m wetland subplot over three rotations, 27 increased and 28 decreased in biomass. The two weed species, kikuyu (*Cenchrus clandestinus*) and saltwater paspalum (*Paspalum vaginatum*) increased in biomass by > 1% (Figure 10c). Both kikuyu and saltwater paspalum are highly invasive grass weeds in Tāmaki Makaurau. They form dense grass swards that displace other plant species and impact bird and invertebrate biodiversity (Graeme and Kendall 2001). Kikuyu thrives in the warm, moist conditions. It shows a strong growth response to nitrogen and is sensitive to low phosphorus levels suggesting its growth could be exacerbated by nutrient enrichment (Cassidy 1972). Saltwater paspalum is saline-tolerant and semi-aquatic, being classed as a wetland facultative (FACW) species. It can be highly invasive in any saline-influenced environment from estuaries and mudflats to brackish creeks where it has a competitive advantage (Graeme and Kendall 2001). Saltwater paspalum is listed in the Auckland Regional Pest Management Plan (2020) under sustained control for the whole region which aims to reduce the spread and impact of this species. Kikuyu is not legally declared a pest. Across the three rotations, saltwater paspalum has been recorded at 4, 6 and 5 sites respectively, but this is not a meaningful measure of its spread since the TBMP does not target saline sites most suited to saltwater paspalum.

Other weeds with increasing biomass were grey willow (*Salix cinerea*), blackberry (*Rubus fructicosus*), Japanese honeysuckle (*Lonicera japonica*), two sedges, broom sedge (*Carex scoparia*) and divided sedge (*Carex divisa*), coral tree (*Erythrina xsykesii*) and woolly nightshade (*Solanum mauritianum*). Across the wetland plot network, two common weeds, reed sweet grass (*Glyceria maxima*) and Yorkshire fog (*Holcus lanatus*) decreased in biomass (by >0.5%) over the 15 years of monitoring. Note that despite this overall decline, some of the plots showing large changes in plant composition between rotation 1 and 3 in the Procrustes analyses (Section 3.3.2) showed an increase in *G. maxima*.

Fifty nationally or regionally Threatened, At Risk or Data Deficient species were recorded in the 10 x 10m wetland subplots over the 15 years of monitoring. Of these, only eight increased in biomass, with the largest increases by the fern *Cyclosorus interruptus* (At Risk- Declining) and the sedge *M. arthrophylla* (Regionally threatened) increasing by >0.1% of biomass (Figure 10d), 11 species showed small declines, and the remaining species were only detected in one rotation, indicating their high vulnerability to local extinction. Twenty-one of these 50 species are wetland obligates requiring wet conditions to survive, while another seven are facultative wetland species that are typically hydrophylic and only occasionally found in non-wetland conditions. All species had low cover and were not widely distributed across the plot network. One of the species, maire tawake (*Syzygium maire*) is an obligate wetland species that is now uncommon over much of its former range due to drainage and vegetation clearance. In addition to these threats, maire tawake is highly susceptible to the wind-dispersed plant pathogen myrtle rust (*Austropuccinia psidii*), along with other Myrtaceae species (Beresford et al 2019). Scrobic (*Paspalum orbiculare*) is easily outcompeted by taller, faster growing shrub and grass species and is therefore highly sensitive to invasion of wetlands by exotic plants. Records of Threatened, At Risk and Data Deficient species were evenly distributed between public and private sites.

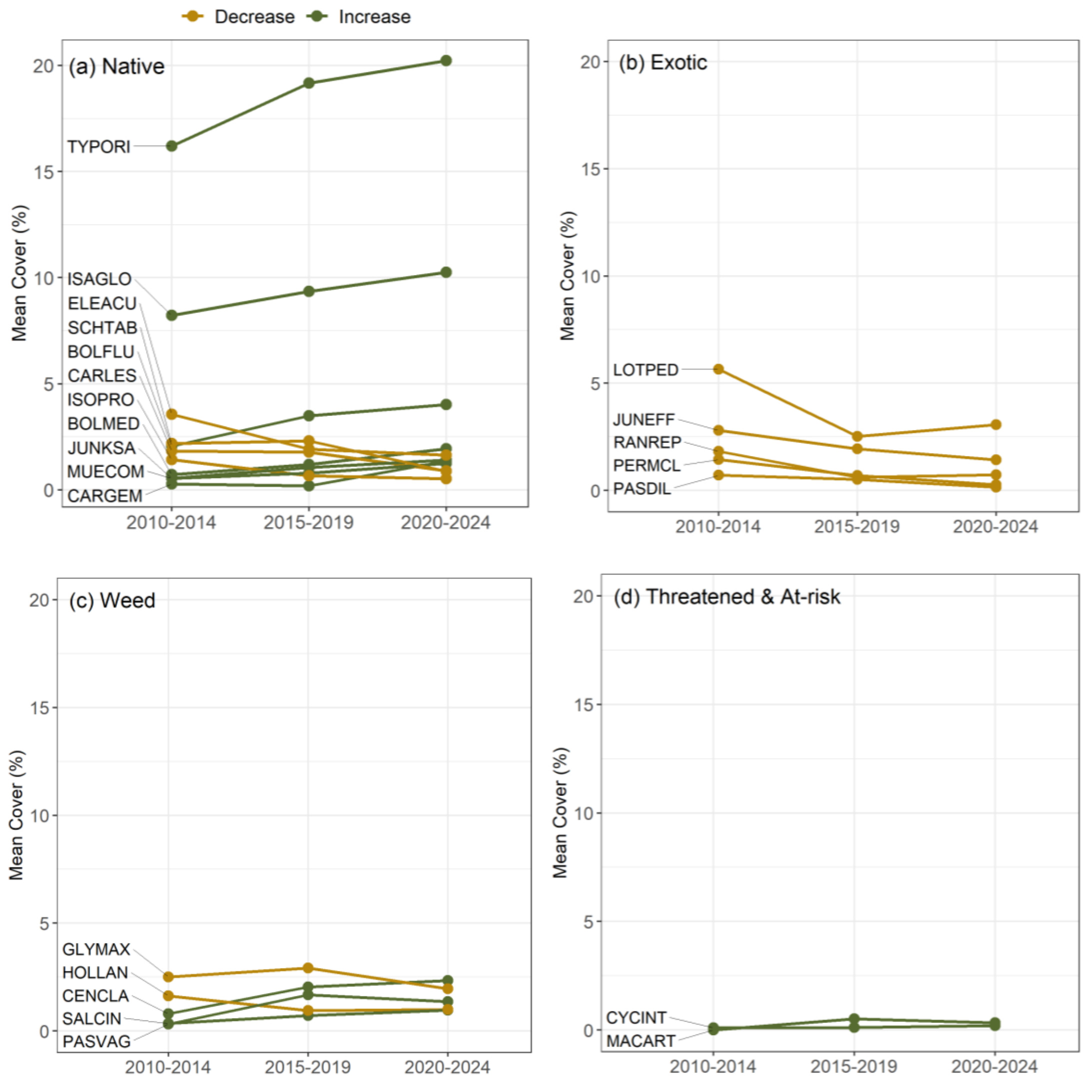

Figure 10. Mean species biomass (relative % species cover) per plot in each rotation for (a) native species (b) exotic species (not including weeds), (c) weeds and (d) threatened or at-risk plants.

3.4 Modified Prevalence Index (PI_{mod})

The PI_{mod} for plots in rotation 3 showed a negative relationship with soil volumetric water content (%, χ^2= 24.0, P<0.001) demonstrating that where the plant community is more hydrophilic, the soil held more water (by volume, Figure 11). This provides some support for the use of the PI_{mod} as an indicator of plot hydrology or 'wetness'. Data for the soil volumetric water content was only available for 151 plots in rotation 3. The PI has an upper threshold of PI ≤ 3 for indicating wetland ecosystems but this was exceeded in many known wetland plots in the TBMP. This suggests that further work is required to optimise the use of the 10 x 10m subplot data, to enable the PI_{mod} to meet thresholds set for the PI. One key difference in the PI_{mod} is the greater weighting given to herbaceous plants versus trees, which could be addressed by for example, using herbaceous cover estimates from the ground layer (0 – 0.3 m) only. The ability to exclude plants not rooted in the plot would also limit the inclusion of more upland species that overhang, are epiphytic or have spread into the plot. Ideally though, different plot methods should be field-tested simultaneously in a range of hydrological regimes alongside hydrological monitoring to fully test this tool and set credible thresholds.

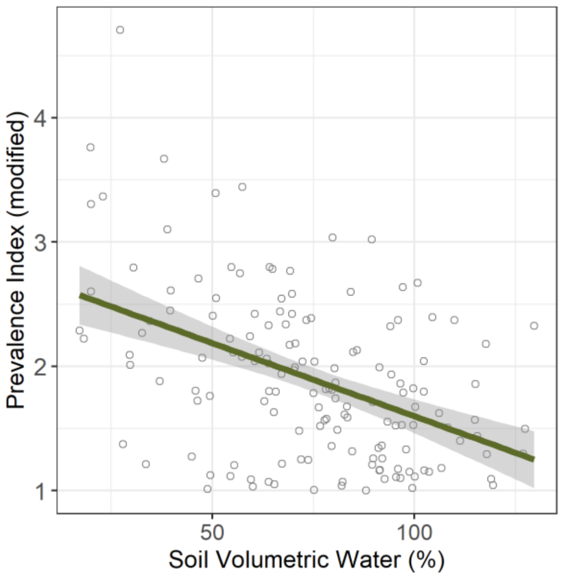

Figure 11. The relationship between the Prevalence Index (modified) and soil volumetric water content (%).

The PI_{mod} varied significantly by wetland class (χ^2= 33.8, P<0.001). Swamp wetlands had a significantly lower PI_{mod} (i.e. they were wetter) than marsh and ephemeral wetlands (Figure 12a), reflecting expected differences in the hydrology of different wetland classes. In swamps the water table is typically at or above the surface in places, while in marshes and ephemeral wetlands the water table can be at or below the surface. Native species were more hydrophilic than exotic species, such that the PI_{mod} is significantly lower when calculated using natives only, compared to exotics only (χ^2= 268.5, P<0.001, Figure 12b).

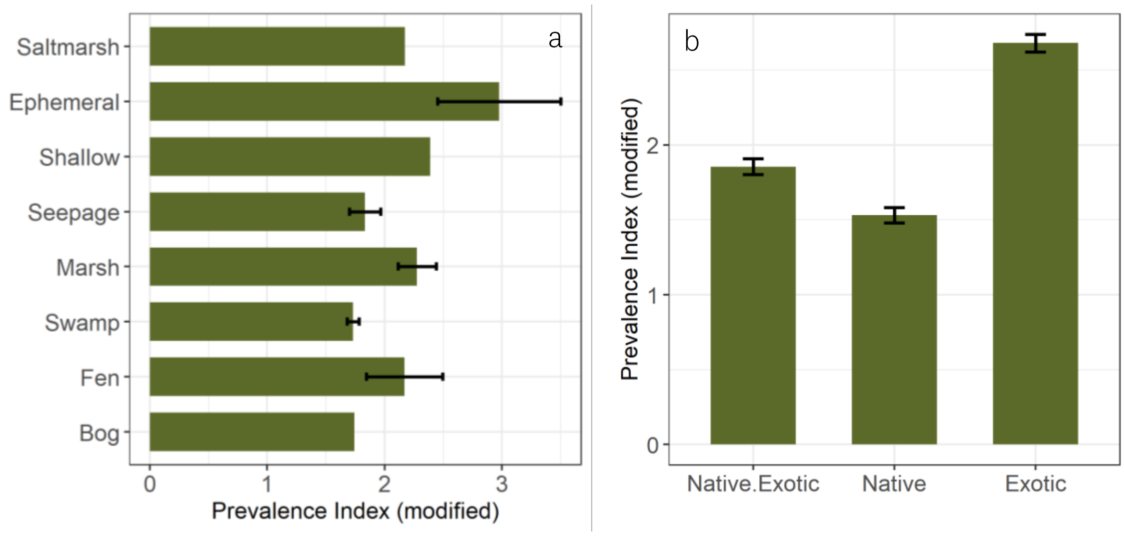

Figure 12. (a) Mean (± 1 s.e.) Prevalence Index (modified) of different wetland classes calculated using the whole plant community of native and exotic species and (b) Mean (± 1 s.e.) Prevalence Index (modified) calculated using Natives and Exotics, Natives only and Exotics only.

There was a positive relationship between PI_{mod} and the biomass of exotic (absolute % species cover, c^2= 89.7, P<0.001, Figure 13a) and weed plants (absolute % species cover, c^2_1=37.4, P<0.001, Figure 13b, calculated using all plots across all rotations). There was no relationship however, between the biomass of exotics or weeds and soil volumetric water content (calculated using the plot data from rotation 3 only), suggesting that weed and exotic biomass is not driven by the wetness of the wetland. This suggests that ingress of exotics and weeds with more upland traits is likely to inflate the PI_{mod} by increasing the score making it appear more upland. The inclusion of plants rooted in upland areas but overhanging the plot may inflate PI_{mod} or PI scores. For example, across the three rotations there has been increasing cover of several pest plants that are upland (UPL) or facultative upland (FACU) vine species (e.g. Japanese honeysuckle *Lonicera japonica*, great bindweed *Calystegia silvatica*, grape *Vitis vinifera*, moth plant *Araijia hortorum*).

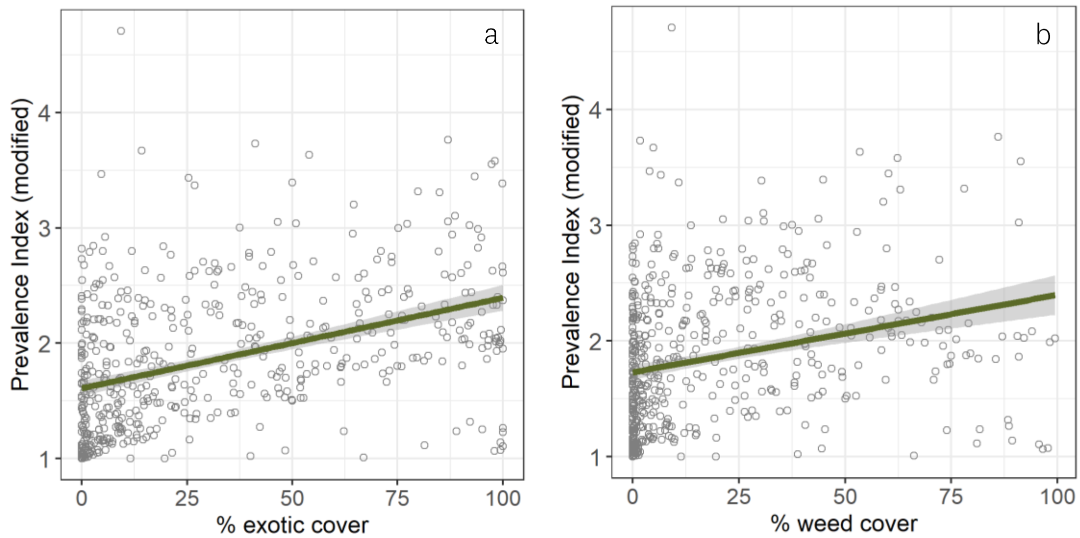

Figure 13. The relationship between the Prevalence Index (modified) and (a) exotic and (b) weed biomass (absolute % species cover) measured for all plots across all rotations.

Figure 13 does shows that in a minority of sites with very low PI_{mod} (<1.4), there were some wetland plots with high % exotic and weed biomass (> 50%, lower-right in graph). The main weed species were the wetland obligate reed sweet grass (*Glyceria maxima,* OBL) and facultative obligate saltwater paspalum (*Paspalum vaginatum*, FACW) which commonly dominate the plant community where they occurred. Water celery (*Heliosciadium nodiflorum*, OBL) was also abundant at some sites (~20% cover). The weeds Yorkshire fog (*Holcus lanatus*, FAC) and alligator weed (*Alternanthera philoxeroides*, FACW) were often present at these wet sites, but only at low biomass (i.e. < 5%). Exotic but non-weed species occurring at these sites included lotus (*Lotus pedunculatus*, FAC), marsh bedstraw (*Galium palustre*, OBL, up to 25% cover in some sites), water forget-me-not (*Myosotis laxa*, OBL), creeping buttercup (*Ranunculus repens*, FAC) and watercress (*Nasturtium officinale*, OBL).

The PI_{mod} of all wetland plots across the region showed no significant trend between 2010 and 2024, suggesting no region-wide systematic shifts indicative of wetlands becoming wetter or drier (Figure 14). Neither were there significant variations in trends for wetlands in different dominant land covers (i.e. urban, rural, indigenous) or for different wetland classes. Individual wetlands however showed large changes in PI_{mod} and hydrology.

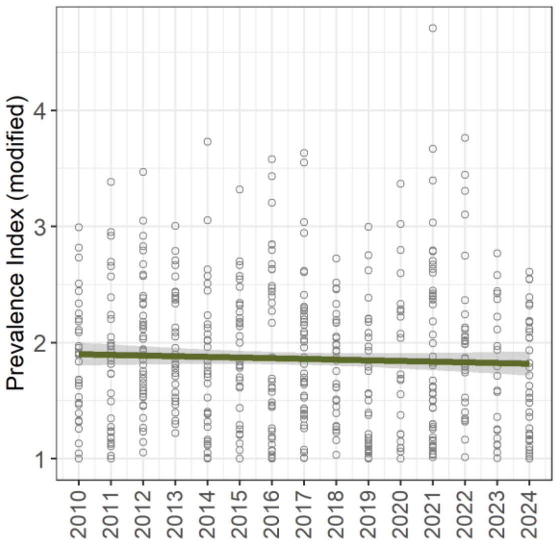

Figure 14. Mean Prevalence Index (modified) of the wetland plant community between 2010 and 2024.

Seven plots showed an increase >0.8 and seven plots showed a decrease of >0.8 in the PI_{mod}. These wetlands were examined further to understand some of the patterns and potential drivers of these changes. A number of geospatial resources were used including historical aerial imagery, stormwater treatment, overland flow paths and substrate drainage.

The seven plots with a large decrease (>0.8) in the PI_{mod} (becoming wetter), were a mixture of public and private wetlands across the region. Five showed both an increase in the biomass of obligate wetland species and a decrease in exotic and weed species biomass. Both indicate a genuine increase in the wetness of the plot.

For most plots it was unclear why wetland plots were becoming wetter. Three showed a large change in land-use, with indigenous forest regeneration within the catchment at two sites and urbanisation at a third. Forest regeneration acts to slow water run-off and increase water infiltration. Where this occurs at sites with imperfect drainage such as Granny's Bay (near Long Bay), the wetland hydrology is likely to be impacted (Figure 15). In urban areas, increased impervious surface area can increase water flow if stormwater is channelled into wetlands. Alternatively, to avoid common contaminants from urban areas entering a wetland, stormwater may be diverted away, resulting in the wetland becoming drier.

Figure 15. Aerial imagery showing forest regeneration of the catchment for the wetland plot at N20B at Granny's Bay (near Long Bay) that is becoming wetter according to the Prevalence Index (modified).

Plots with a large increase (>0.8) in the PI_{mod} (becoming drier), were a mixture of public and private wetlands across the region. Three of the plots showed a big increase in the biomass of weed and exotic species, increasing biomass of plants with more facultative upland and upland traits. Similar decreases in the biomass of obligate plant species indicate plants are responding to drying of the wetland. The plot showing the greatest increase in the PI_{mod} (+2.8) is on a private wetland so images identifying it cannot be shown. This ephemeral wetland is in a well-drained area on sandy substrate surrounded by pine plantation. Pine plantations can have a drying effect on surrounding land due to increased interception and evapotranspiration by these fast-growing trees. The drying effect detected in this plot is not inflated by increasing biomass of exotic or weed upland species as exotic biomass was stable and there was a large decline in weed biomass, especially between rotation 2 and rotation 3.

3.5 Wetland condition, pressure and edge indices

The WCI and WPI are nationally used indicators of wetland condition and pressure (Clarkson et al 2004) used widely by several regional and district councils in Aotearoa New Zealand and made available for use by community groups (Denyer and Peters 2014). The WEI was developed for the TBMP wetland protocol when it started in 2010 to describe the perimeter of a wetland, which can have a big impact on wetland condition (Denyer et al 2011). The results of these indices are presented and strengths and weaknesses discussed.

3.5.1 Wetland condition index

(a) State

Wetlands monitored in the last five years had a mean Wetland Condition Index (WCI) of 18.8 (± 0.2) out of 25. Of the 163 wetland sites, 37% were scored as being in excellent condition, 53% in good condition, 9% in moderate condition and one in a degraded condition (score 9.7, Table 6). The 60 wetland sites in excellent condition were distributed across the region and located in indigenous and exotic forestry, rural and urban landscapes; two-thirds were on public land. The one degraded wetland was a privately-owned swamp in Manukau surrounded by exotic grassland and horticulture where only three of the 28 plant species were indigenous, and seven were invasive weeds.

Table 6. Number and % of wetlands monitored in the last five years (2020-2024) scored for the Wetland Condition Index (WCI), Wetland Pressure Index (WPI) and Wetland Edge Index (WEI).

Index	Score category	Number of plots	% of plots
Wetland Condition Index (WCI)	Excellent	60	37
	Good	87	53
	Moderate	15	9
	Degraded	1	1
Wetland Pressure Index (WPI)	Low pressure	20	12
	Medium pressure	111	68
	High pressure	32	20
Wetland Edge Index (WEI)	Good	40	24
	Moderate	107	66
	Poor	16	10

More can be understood about what is impacting wetland condition by examining sub-indicator scores for Excellent, Good, Moderate or Degraded wetlands. The sub-indicator scores for WCI show that there is generally little or no evidence of harvesting (HARVL) and recent vegetation damage or clearance (VEGDA) is rare. In contrast, impacts from pest predators (IPRED) and introduced (exotic) plants in the canopy (ICANO) and understorey (IUNDE) are relatively ubiquitous (Table 7). Introduced plants in the understorey were more widespread than introduced plants in the canopy. Only nine (of 163) sites showed little or no impacts of introduced predators, seven of these were publicly owned sites with high conservation management including Tāwharanui, Shakepear and Long Bay Regional Parks and on Motutapu Island Recreation Reserve. Ten sites (of 163) scored high, very high or extreme for introduced predator impacts (ie score ≤ 2), eight of these were in the Kaipara ecological district and seven were privately owned and managed.

For those wetlands in moderate condition, key impacts came from introduced predators and plants, changes to the water table depth (WTABLE), loss of original wetland area (AREAL), nutrient levels (NUTLE) and sedimentation (SEDIM). All sites scoring 2 or less for the water table sub-indicator were in the Kaipara ecological district. A score of 2 or less indicates at best (score = 2), that the water table was lowered for long periods during dry spells, or the average water table has noticeably declined over time, and at worst (score = 0) that the wetland is now effectively a 'dryland' (or had been artificially flooded). Wetlands in the Kaipara ecological district are often on sandy substrate with good drainage, and several are close to pine plantation that can have a drying effect on surrounding land by increased interception and evapotranspiration by these fast-growing trees.

Sixteen wetlands have lost more than 50% of their presumed original (pre-human) wetland area (scoring ≤ 2, 11 of 163 wetlands have lost > 75% of their original area). Given that 96% of the original wetland extent has been lost, it is surprising this are not higher. Twenty-four wetlands showed signs of high to extreme nutrient enrichment (scoring ≤ 2) including ≥ 50% of the wetland showing algal blooms, or vegetation change to high-nutrient species. All were in rural or urban landscapes. Twelve wetlands showed high to extreme sedimentation, with visible sediment deposits (or scouring) affecting ≥ 50% of the wetland. Again, these wetlands were predominately on private land in rural landscapes. Nine of these wetlands scored high (<=2) for both nutrient enrichment and sedimentation.

Table 7. Sub-indicator scores (mean ± s.e.) for the Wetland Condition Index (WCI).

Wetland Condition Index sub-indicators			Excellent		Good		Moderate		Degraded	
			mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.
Browsing, predation & harvesting	Harvesting levels	HARVL	5.0	0.0	4.9	0.0	5.0	0.0	5.0	0.0
	Introduced predator impacts	IPRED	3.3	0.1	2.3	0.1	1.4	0.2	0.0	0.0
	Domestic/feral animal damage	UNGUL	4.7	0.1	4.1	0.1	2.9	0.4	1.0	0.0
Dominance of native plants	Introduced plant canopy	ICANO	3.9	0.1	3.1	0.1	1.6	0.2	1.0	0.0
	Introduced plant understorey	IUNDE	3.7	0.1	3.0	0.1	1.1	0.2	0.0	0.0
Ecosystem intactness	Loss of original wetland	AREAL	4.6	0.1	3.9	0.1	2.5	0.4	4.0	0.0
	Hydrological connectivity barriers	HYBAR	4.5	0.1	3.5	0.1	2.9	0.5	2.0	0.0
	Vegetation damage	VEGDA	5.0	0.0	4.9	0.0	4.5	0.3	5.0	0.0
Hydrological integrity	Dryland plant invasion	DPLAN	4.2	0.1	3.7	0.1	3.2	0.3	1.0	0.0
	Manmade structures	MANMS	4.4	0.1	3.6	0.1	2.7	0.5	1.0	0.0
	Water table depth	WTABLE	4.1	0.2	3.7	0.2	2.4	0.4	4.0	0.0
Physiochemical parameters	Nutrient levels	NUTLE	4.2	0.1	3.4	0.1	2.5	0.2	1.0	0.0
	Sedimentation/erosion	SEDIM	4.2	0.1	3.6	0.1	2.5	0.3	2.0	0.0
	Von post index (peat bogs only)	VONPO	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0

(b) Trend

There was a small but significant increase in the WCI across the 163 wetlands sampled in rotation 1 (2010-2014), rotation 2 (2015-2019) and rotation 3 (2020-2024, χ^2_2= 12.7, P<0.001, Figure 16a). This was driven by small shifts in many WCI sub-indicators, with small but significant improvements in harvesting levels (HARVL, χ^2_2= 10.9, P<0.01), vegetation damage (VEGDA, χ^2_2= 6.9, P<0.05) and hydrological connectivity barriers (HYBAR, χ^2_2= 8.2, P<0.05, Figure 16b).

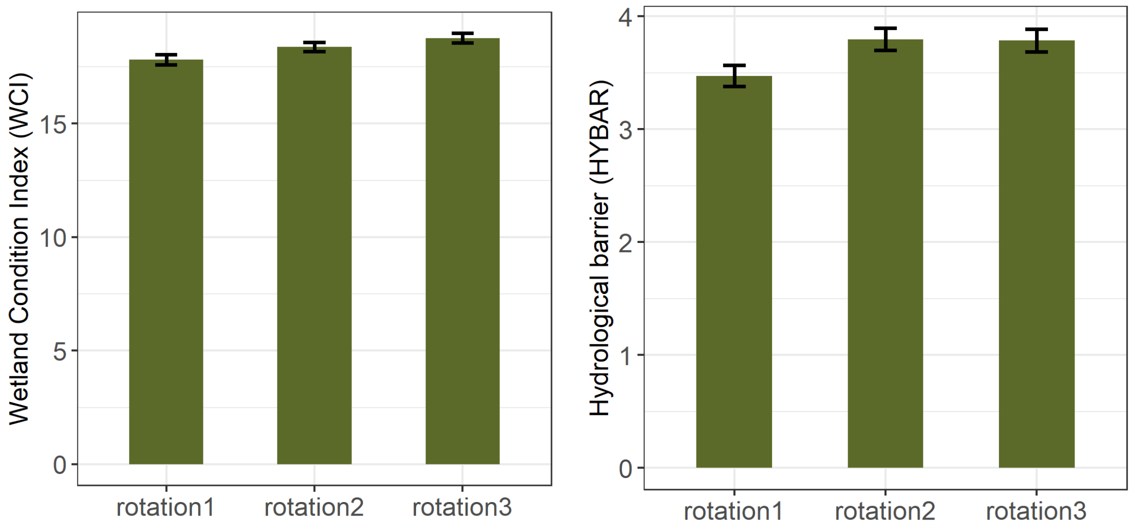

Figure 16. (a) Mean (± 1 s.e.) Wetland Condition Index (WCI) for wetlands sampled across the rotations (rotation 1: 2010-2014; rotation 2: 2015-2019; rotation 3: 2020-2024, n= 189 plots). (b) Mean (± 1 s.e.) Hydrological connectivity barrier score for all 189 wetlands sampled across the rotation.

(c) Strengths and weaknesses

Several of the WCI sub-indicators are difficult to score in the field and/or with only one wetland visit every five years. These include Harvesting levels (many types of harvesting will leave few or no signs), Introduced predator impacts (reliant on detecting on the day of the wetland visit signs of pest animals, predator trapping, or indigenous species sensitive to predator impacts), Domestic/Feral animal damage (reliant on detecting on the day of the wetland visit signs of domestic or feral animals, fencing, assumptions that fencing is maintained and complete), Loss of original wetland (in the field this is often based on topography and the assumed wetland footprint), Water table depth (can be difficult to assess changes in water table without prior knowledge of the wetland, this component indicator is also difficult to interpret without additional notes as scores can indicate drying or wetting). In addition, many of these scores are subjective and teams will score them differently. In the third rotation on the TBMP, previous scores were supplied to field teams to try to improve the consistency of scoring, and the value of making notes to justify scores was emphasised.

Other WCI sub-indicators are more reliably scored in the field with a single visit. Furthermore, several sub-indicators can be assessed against data collected from the plot. For example, the sub-indicators Introduced plant canopy cover (R = -0.58, P < 0.001) and Introduced plant understorey cover (R = -

0.61, P < 0.001) were both significantly and negatively correlated with exotic plant biomass (absolute % species cover) measured in the 10 x 10m subplot, and the Dryland plant invasion (R = -0.31, P < 0.001) sub-indicator was significantly and negatively correlated with upland and facultative upland plant biomass (absolute % species cover) in the 10 x 10m subplot (Figure 17). Despite these significant correlations, there remains a large variation in scoring and biomass cover at individual sites. Scoring of high Dryland plant invasion (score of 0 – 2) was particularly weak.

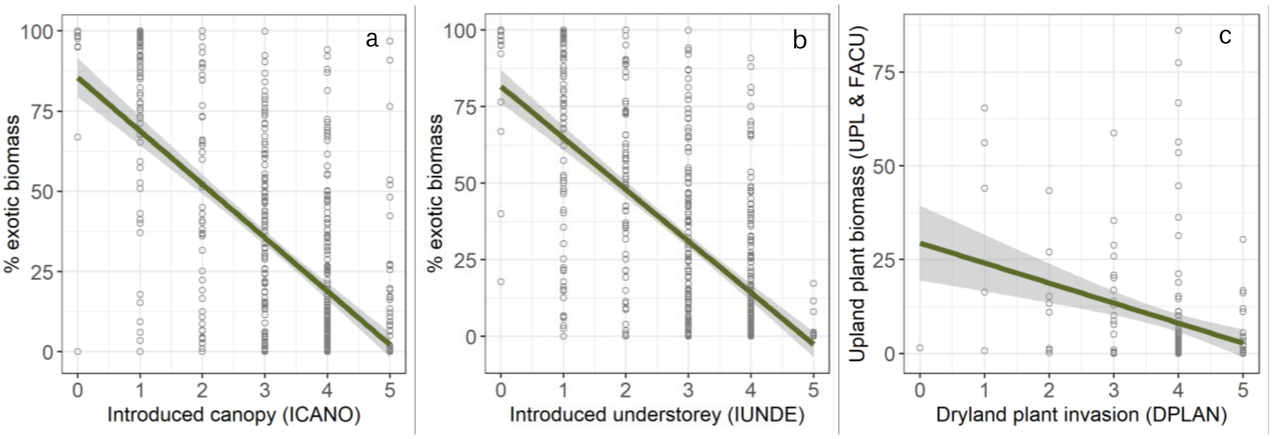

Figure 17. Relationship between Wetland Condition Index sub-indicators and related parameters collected in the 10 x 10m subplot. (a) Introduced plant canopy cover (ICANO) sub-indicator and % exotic plant biomass (relative % cover), (b) Introduced plant understorey cover (IUNDE) sub-indicator and % exotic plant biomass (relative % cover), and (c) Dryland plant invasion (DPLAN) sub-indicator and % upland (UPL) and facultative upland (FACU) plant biomass (relative % cover).

3.5.2 Wetland pressure index

(a) State

The mean Wetland Pressure Index (WPI) score for wetlands monitored in the last five years was only 15.5 (± 0.4) out of 30. Of the 163 wetland sites, 12% were scored as low pressure, 68% had moderate pressure and 20% had a high pressure score, indicating that these 32 sites are under multiple pressures (Table 8).

Overall, wetlands categorised as having low pressure had few Modifications to the catchment hydrology (HYDRO); were generally within 100m of other freshwater or saline wetland (WISOL); and showed little or no Catchment water quality decline (WQUAL, Table 7). Even wetlands with a low pressure score however, had threats to ecological integrity from the presence of up to four Key undesirable plant species in the catchment (KEYUP) and some Animal pest presence (APEST). Of the 20 (of 163) wetlands with a low pressure score, many were in predominately indigenous landscapes and 16 were on publicly owned and managed land including seven Regional Parks (Waitawa, Waitākere Ranges, Long Bay, Hūnua Ranges, Shakespear, Tāwharanui and Mahurangi).

Wetlands categorised as under high pressure had little impediment to Animal pest presence; >75% of the Catchment hydrology had been modified; and >75% of the catchment was in introduced vegetation (PCTIV). In addition, there were more than five Key undesirable plant species found within the catchment and moderate pollution including possible sedimentation and nutrient enrichment indicating Catchment water quality decline. Generally, Wetland isolation was low, with wetlands within 500m of another freshwater or saline wetland on average. The 32 (of 163) wetlands under high pressure were all in rural, urban or exotic forestry dominated landscapes, and 20 were in private ownership.

Table 8. Sub-indicator scores (mean ± s.e.) for the Wetland Pressure Index (WPI).

Wetland pessure Index sub-indicators		Low pressure		Medium pressure		High pressure	
		mean	s.e.	mean	s.e.	mean	s.e.
Animal pest presence (excl stock)	APEST	1.7	0.2	2.9	0.1	4.2	0.1
Catchment hydrology modifications	HYDRO	0.9	0.2	3.1	0.1	4.3	0.1
Key undesirable plant species in catchment	KEYUP	2.1	0.2	2.6	0.1	3.7	0.2
% catchment in introduced vegetation	PCTIV	1.3	0.1	3.0	0.1	4.1	0.1
Wetland isolation	WISOL	0.4	0.2	1.2	0.1	1.8	0.2
Catchment water quality decline	WQUAL	0.8	0.1	2.3	0.1	3.5	0.1

(b) Trend

No change in the Wetland Pressure Index (WPI) was recorded over the three rotations, but there was an increase in both the presence of Key undesirable plant species occurring within the catchment (χ^2_2= 13.5, P<0.01, Figure 18a) and Modifications to the catchment hydrology (χ^2_2= 8.6, P<0.05, Figure 18b). Pest plants continue to be an increasing pressure in wetlands and would be expected to increase where they are unmanaged.

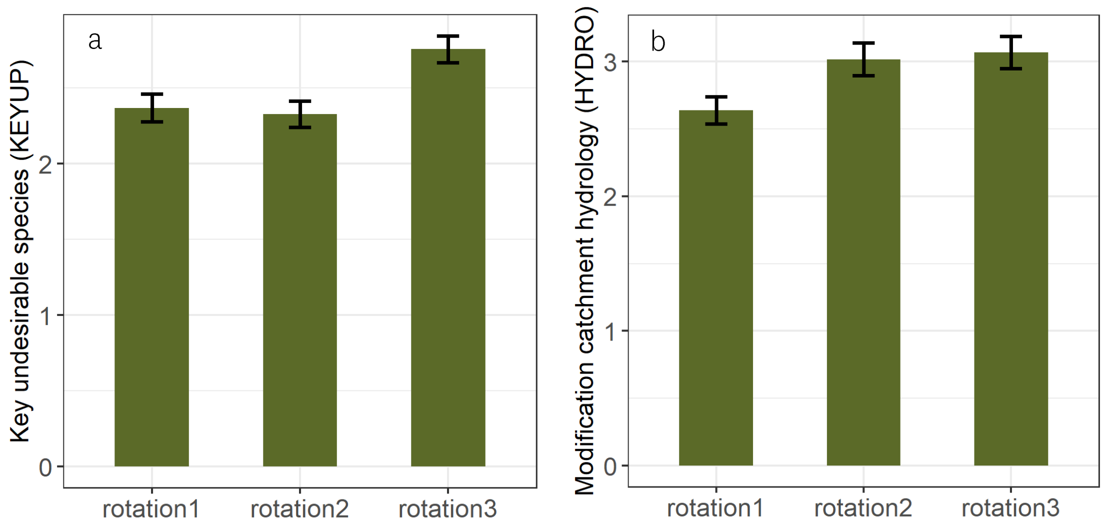

Figure 18. Mean (± 1 s.e.) scores for two Wetland Pressure Index sub-indicators measured per rotation (rotation 1: 2010-2014; rotation 2: 2015-2019; rotation 3: 2020-2024, n= 189 plots). (a) Key undesirable species (KEYUP), (b) Modifications to catchment hydrology (HYDRO).

(c) Strengths and weaknesses

Further examination of the sub-indicator Modifications to catchment hydrology at a plot level suggests they were not scored in a consistent way between rotations, requiring further investigation. For example, in Modifications to the catchment hydrology, the area considered as the hydrological catchment may have differed between teams/visits. Other regional councils have also had difficulties in consistently scoring Modifications to catchment hydrology and are exploring use of remote sensing and geospatial analysis. Scoring for Animal pest presence makes key assumptions that observed signs of fencing or predator trapping are maintained and effective. The sub-indicator Catchment water quality was compared against abiotic parameters of soil and foliage nutrients and ratios collected during the same plot visit (Figure 19). Soil phosphorus ($R = 0.2$, $P < 0.05$) showed a weak positive relationship with Catchment water quality decline indicating higher soil phosphorus content when wetlands scored high pressure. Foliage nitrogen:phosphorus ($R = -0.17$, $P < 0.05$) showed a weak negative relationship with Catchment water quality decline indicating elevated foliage phosphorus content relative to nitrogen when wetlands scored high pressure.

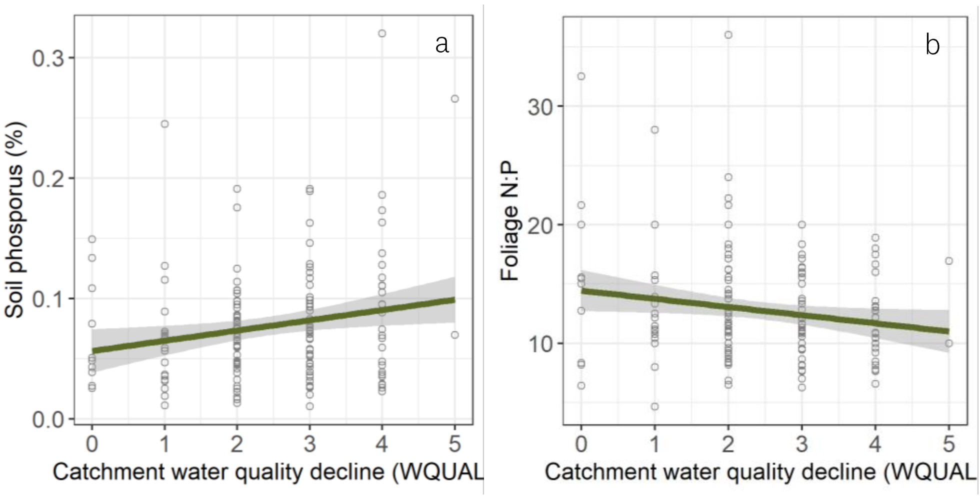

Figure 19. Relationship between Wetland Pressure Index sub-indicator Catchment water quality decline (WQUAL) and related abiotic parameters collected on the wetland visit. (a) Soil phosphorus (P, %), and (b) Foliage nitrogen:phosphorus ratio (N:P).

3.5.3 Wetland edge index

(a) State

The mean Wetland Edge Index (WEI) score was 17.5 (± 0.4) out of 30. Of the 163 wetland sites monitored, 40% had good edge condition, 52% moderate and 8% poor edge condition. Poor edge condition indicated modifications and high weed density in the buffer zone, stock access and drainage (Table 9).

Wetlands categorised as having good edge condition had little or no canopy dieback at the wetland edge (first 3m, CANOPY); had few perimeter drains (PDRAINS); and the wetland was securely fenced and/or not in grazing land (STOCK). Wetlands with a good edge condition were skewed towards public land (44 of 66 wetlands were on public land) and were in all dominant landcover types.

Wetlands with poor edge condition had no buffer, with no surrounding indigenous vegetation and grazing or mowing to the wetland edge (PBUFFER); drains are present with water visibly seeping from the sides or flowing along the drain, and dryland plant species are common (PDRAINS); the wetland has a high edge to area ratio (SHAP); and more than half the perimeter plant species are exotic in any vegetation height tier (WEED). The 13 wetlands with poor edge condition were predominately in landscapes dominated by rural landcover and were skewed towards private ownership (8 of 13 wetlands).

Table 9. Sub-indicator scores (mean ± s.e.) for the Wetland Edge Index (WEI).

Wetland Edge Index sub-indicators		Good		Moderate		Poor	
		mean	s.e.	mean	s.e.	mean	s.e.
Canopy dieback	CANOPY	4.4	0.1	4.1	0.1	1.6	0.5
Perimeter buffer	PBUFFER	3.5	0.2	1.5	0.1	0.2	0.1
Perimeter drains	PDRAINS	4.7	0.1	3.8	0.2	1.8	0.6
Shape index	SHAP	1.7	0.1	1.3	0.1	0.4	0.2
Stock access	STOCK	4.8	0.0	3.8	0.2	0.5	0.3
Weed density	WEED	2.7	0.1	1.8	0.1	0.1	0.1

(b) Trend

The Wetland edge indicator, a measure of condition at the perimeter of the wetland, showed no trend over the three rotations. There were some minor shifts in individual sub-indicator scores with a small increase in canopy dieback (a decline in canopy dieback condition) and a small decrease in the number of weeds in the wetland perimeter (an increase in weed condition) but nothing significant.

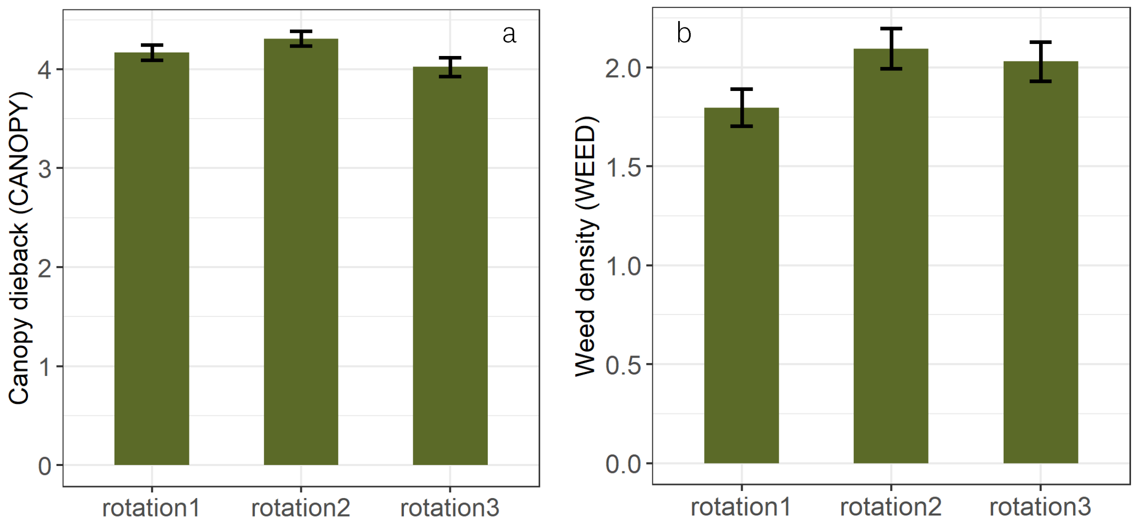

Figure 20. Mean (± 1 s.e.) scores for two Wetland Edge Index sub-indicators measured per rotation (rotation 1: 2010-2014; rotation 2: 2015-2019; rotation 3: 2020-2024, n= 189 in total). (a) Canopy dieback (CANOPY), and (b) Weed species abundance (WEED).

(c) Strengths and weaknesses

Although subjective, this index provides valuable information relating to the wetland perimeter buffer, perimeter drains and canopy dieback that are not well captured elsewhere in the protocol. These sub-indicators can help to guide conservation management.

3.6 Abiotic parameters

The suite of abiotic parameters measured in the TBMP have been recommended nationally to support wetland classification and condition monitoring, and to identify nutrient enrichment of wetlands, while recognising that the use of these tools for monitoring wetlands remain in development (Clarkson et al 2004, Clarkson et al 2015).

Abiotic data are presented here to describe the current state (2020 – 2024) of wetlands in the TBMP (the first complete rotation with abiotic data), organised by wetland class. Abiotic parameters will be most representative for swamps and marshes which form the vast majority of wetlands monitored in the TBMP. Foliage nutrient data is analysed for raupō to examine potential patterns of nutrient enrichment in TBMP wetlands.

3.6.1 Abiotic measurements organised by wetland class

Field application of wetland class is complex and use of the plot-based plant composition data to verify wetland class is imperfect due to a mismatch in scales (i.e. 10 x 10m plot vs. wetland). Abiotic parameters however are a defining characteristic of wetlands (Johnson & Gerbeaux 2004) and attempts at setting quantitative limits for some parameters and wetland classes have been made using data from the national wetland database held by Manaaki Whenua Landcare Research. (Clarkson et al 2015).

(a) Field measures

Field measures are recorded in the field where there is water, measurement of this data has been inconsistent and indication of whether the water table was above ('+') or below ('-') the soil surface was omitted in some records. Therefore, these data are incomplete. Furthermore, efforts to generate quantitative limits for wetland classes have used soil parameters rather than wetland parameters (Clarkson et al 2015). While water-based parameters can be easier, cheaper and cause less disturbance, they can also fluctuate widely and may be less meaningful for monitoring on a 5-year return time.

Bog waters tend to be acidic, so the low pH for the single bog in the TBMP looked appropriate but water pH for fen and swamp wetlands is elevated (Figure 21). Electrical conductivity measures dissolved salt concentrations in the water and can indicate salinity. The electrical conductivity of fresh groundwater is typically < 150 µS/cm, while seawater has an electrical conductivity of 50,000 µS/cm. Some swamp sites are clearly showing signs of low-level salinity. Water temperature will fluctuate widely depending on the weather, presence of a shade-forming canopy, etc. Highest temperatures were recorded in more open wetland classes.

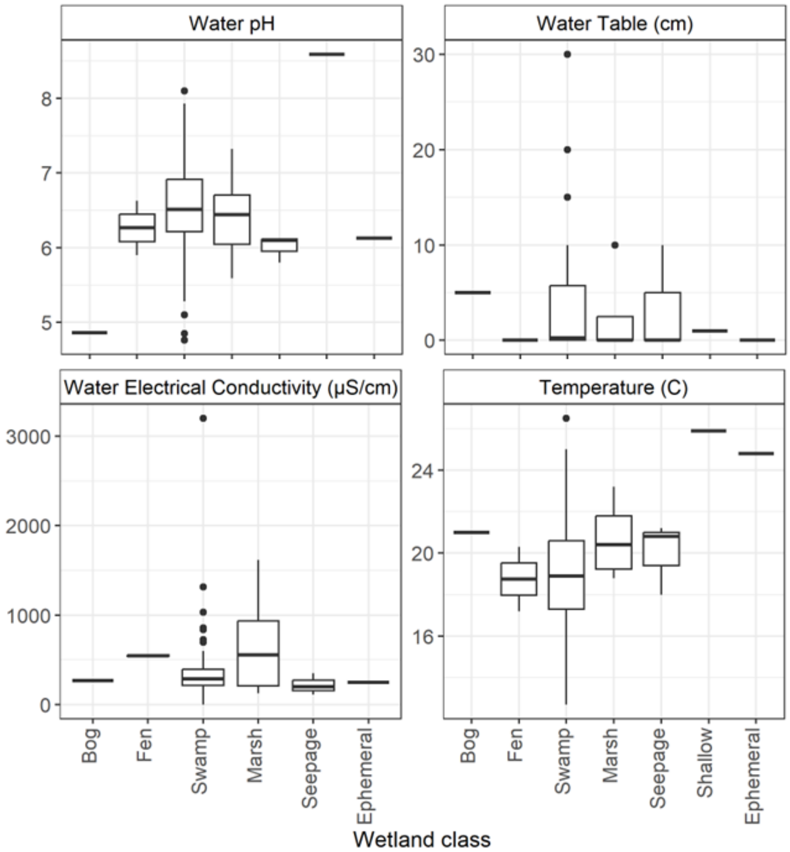

Figure 21. Boxplots of water pH, water table, water electrical conductivity and water temperature by wetland class for rotation3 (2020-2024).

(b) Soil parameters

Along a gradient of bog, fen, swamp, and marsh, wetland soils were shown to increase in pH and phosphorus and decrease in carbon and N:P ratios (Clarkson et al 2015). Changes in soil pH can be indicative of hydrological change. Mean soil pH for bogs scored to be in excellent condition was 4.5 (3.9 – 5.0), a much lower pH than that recorded for the single bog in the TBMP (Figure 22, Clarkson et al 2015). Mean soil pH for swamps scored to be in excellent condition was 5.7 (4.8 – 6.3) which compares well with swamp soil pH in the TBMP. Marsh wetlands are expected to have a more neutral pH (~7).

Soil electrical conductivity is used to quantify salinity and will be valuable to assess saline wetlands, detect saltwater intrusion into palustrine wetlands or even sea-level rises on the coastal margin. Salinity can have a big impact on plant growth and elevated levels will influence species composition. Several swamp wetlands showed high electrical conductivity more expected of brackish water. Soil bulk density was 0.164 (0.06 – 0.25) for swamps in excellent condition, generally lower than soil bulk density for swamps in the TBMP (Clarkson et al 2015). Soil bulk density is useful for converting between gravimetric and volumetric measures of soil nutrients. For swamps in excellent condition, nitrogen content (%) was found to be 1.4 (0.6 – 2.0), slightly higher than that observed in the TBMP swamps (Figure 23), while carbon content (%) was found to be 26.2 (8.9 – 42.7), much higher than that observed for TBMP swamps (Clarkson et al 2015). Soil carbon affects many soil properties and functions including soil resilience; declines in soil carbon in wetlands can indicate changing water levels and emission of greenhouse gases (Thompson-Morrison and McNally 2024).

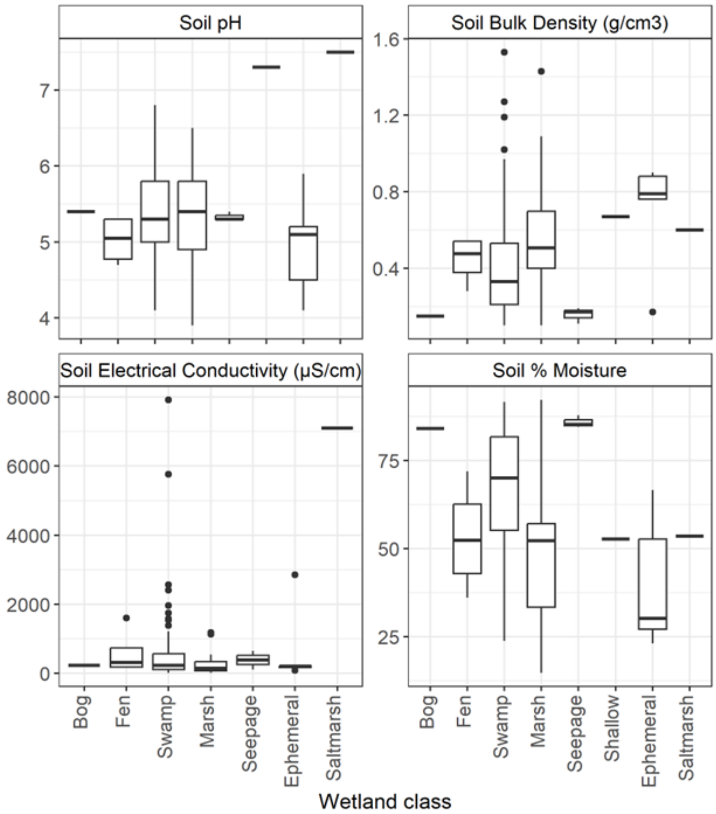

Figure 22. Boxplots of soil pH, soil bulk density, soil electrical conductivity and soil moisture by wetland class for rotation3 (2020-2024).

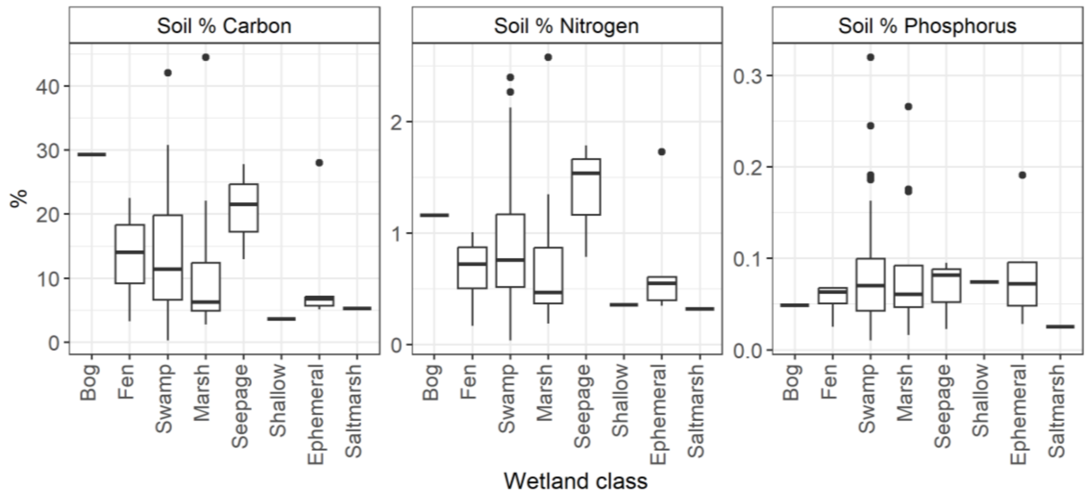

Figure 23. Boxplots of soil carbon (C), nitrogen (N) and phosphorus (P) by wetland class for rotation3 (2020-2024).

(c) Foliage nutrients

Foliage nutrient content can better reflect the nutrients available for plant growth over a growing season, compared to nutrient levels in soil or water that can fluctuate rapidly in response to biological processes (nitrification, denitrification and mineralisation) and temporal variability (e.g. seasonal cycles in response to plant growth or rainfall, land-use activity). Water nitrogen levels can also be rapidly depleted in response to plant growth. Nutrient levels of the two most limiting nutrients, nitrogen (N) and phosphorus (P) can be used individually or as ratios. Nitrogen (%) and phosphorus (%) levels in TBMP wetlands had a higher upper range than wetlands analysed by Clarkson et al (2015).

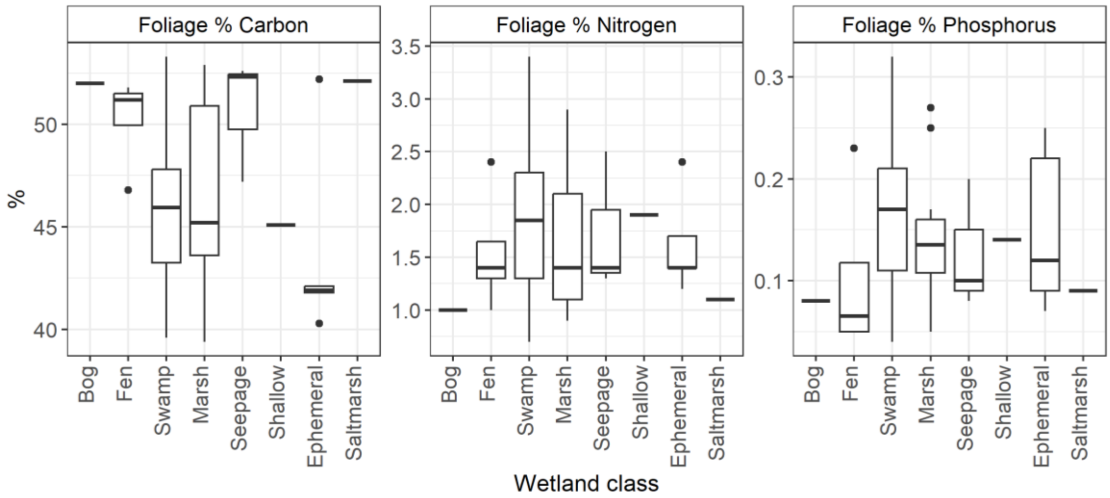

Figure 24. Boxplots of foliage carbon (C), nitrogen (N) and phosphorus (P) by wetland class for rotation3 (2020-2024).

3.6.2 Use of foliage nutrient data to understand wetland enrichment

Increasing biomass of raupō (absolute % species cover) and a corresponding decline in species richness are structural indicators of nutrient enrichment, while foliage nutrients provide biogeochemical indicators (Figure 25).

Raupō is a widespread and abundant indigenous plant occurring in 81 of the 163 plots and composing 20% of all plant biomass in rotation 3 (2020 – 2024). It has also been increasing in biomass over the 15-years of monitoring. Data showed a negative relationship between raupō biomass in a plot and species richness ($\chi^2 = 8.5$, $P < 0.01$); where raupō was dominant in a plot there were significantly fewer species (Figure 25a). Raupō generally showed highest increases in biomass in plots where it was already abundant.

Plant growth is most likely to respond to elevated nutrient levels when they are normally limited (Figure 25b). In oligotrophic (low nutrient) wetlands, nitrogen limited wetlands have a N:P < 14 (plots above the diagonal dashed green line) and P-limited wetlands have a N:P > 16 (plots below the diagonal yellow line, Koerselman and Meuleman 1996) inside of commonly used thresholds for nitrogen limitation of < 2% foliage nitrogen (indicated by the grey vertical line) and < 0.1% foliage phosphorus (indicated by the grey horizontal line, Clarkson et al 2004), indicating that most TBMP wetlands are N-limited. Swamp and marsh wetlands most typical of the TBMP however, typically have moderate to high nutrient status (Johnson & Gerbeaux 2004), and thresholds for these wetlands and the plants growing in them may differ. Wilby et al (2001) also found that plants with different functional traits showed systematic differences in their foliage nutrient ratios. Given the documented growth response of raupō to elevated nitrogen levels, even up to very high concentrations (Wang et al 2015, Yu et al 2019, Trang et al 2022), it is highly possible that raupō is nitrogen-limited in most TBMP wetlands.

In raupō, the foliage C:N and C:P ratios were highly correlated and both showed a similar relationship with biomass and changes in biomass, however only the relationship between foliage C:N ratio and raupō biomass was significant. Raupō biomass was highest and showed largest increases (yellow circles) where nitrogen levels were elevated, indicated by low foliage C:N ratio ($\chi^2 = 17.5$, $P < 0.001$, Figure 25c). Wetlands can have both elevated nitrogen levels, to which raupō will rapidly respond, and remain N-limited relative to phosphorus. Foliage N:P showed no differences between dominant land cover types (urban, rural, indigenous forest or exotic forest) in 1000m buffers surrounding the wetland plot.

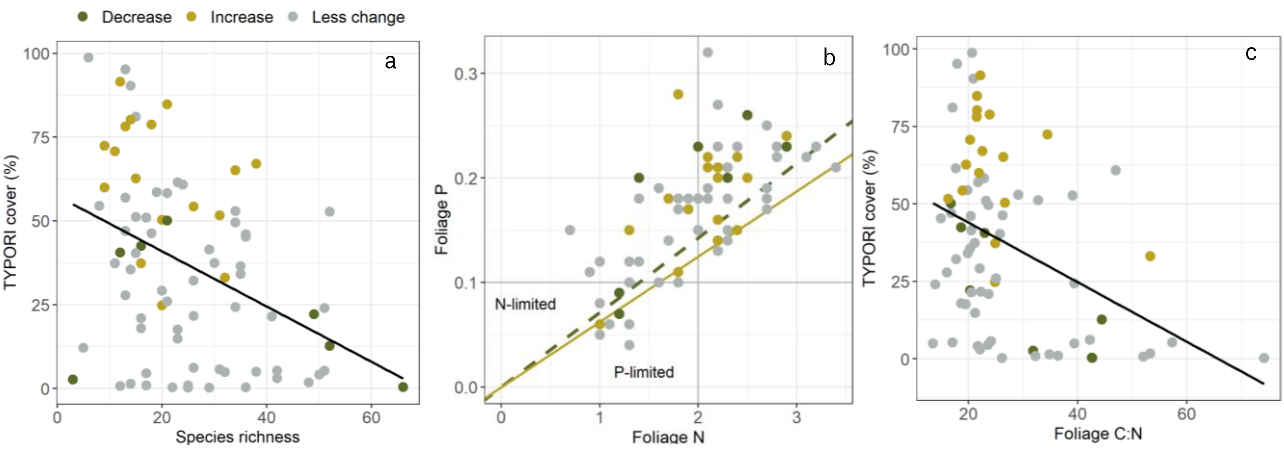

Figure 25. Raupō biomass (absolute % species cover) in rotation3 and changes in biomass between rotation1 and rotation3 in relation to (a) plot species richness, (b) relationship between foliage N and foliage P, and (c) Raupō biomass and foliage C:N, at a plot. Biomass values are coloured by whether raupō showed large increases (>20% cover, yellow), large decreases (>20% cover, green) or less change (grey) between rotation1 and rotation3.

Foliage nutrients are valuable parameters to understand wetland ecological functioning and can be used in many other ways. The use of raupō as an indicator of nutrient enrichment is promising. Raupō has increased in distribution and abundance globally and in Aotearoa New Zealand in response to human disturbance and nutrient enrichment (Li et al 2024). Given its growth response to nutrient enrichment, it can play a role in removing nutrients from the water during the growing season and thereby protect downstream water quality. Without harvesting however, a large proportion of these nutrients will be returned to wetlands during decomposition (Yu et al 2019). Raupō has long been sustainably harvested by tangata whenua for food, medicine, weaving and building materials; harvesting this species could also promote improved water quality and wetland restoration (Li et al 2024). With continued monitoring of foliage nutrients in the TBMP it will be possible to identify how nutrient levels are changing through time, while further analyses should identify wetlands showing signs of enrichment and investigate potential nutrient sources.

4 Conclusions

This report describes the state and trends in plant biodiversity and wetland ecological integrity in Tāmaki Makaurau from 2010 – 2024, using data from Auckland Council's Terrestrial Biodiversity Monitoring Programme (TBMP) wetland plot network. The TBMP provides long-term, systematically collected and quantitative data on wetland plant and bird composition, structure and function, semi-quantitative assessments of wetland condition, pressure and perimeter habitat, and quantitative data on abiotic parameters. Most wetlands in the TBMP are palustrine or freshwater wetlands that meet the definition of natural inland wetland as defined by the National Policy Statement on Freshwater Management (NPS-FM, MfE 2022).

4.1 Wetlands under pressure

Analysis of plot and index data revealed the exotic plant burden in wetland communities. Exotic species comprised 49% of all recorded species and weeds accounted for 21% of total plant biomass. This pattern aligns with similar studies showing that wetlands, as receiving environments especially in highly modified landscapes, are particularly vulnerable to exotic and pest plant invasion (Bird et al 2024). Pest plants that are especially widespread and/or increasing in biomass in wetland plots include kikuyu, mercer grass, saltwater paspalum, reed sweetgrass, grey willow, blackberry, Japanese honeysuckle, broom sedge, divided sedge, coral tree and woolly nightshade. Crack willow (*Salix fragilis*) and alligator weed (*Alternathera philoxeroides*) were also present. Many of these species can become dominant in their environment, outcompeting indigenous species leading to biodiversity loss, and fundamentally changing wetland hydrology and other ecosystem functions.

Over the 15-year monitoring period, there was shown to be substantial turnover in indigenous plant species composition and structure. The general pattern was that plant communities were diverging from their earlier states, and this directional change was consistent with anthropogenic pressures rather than natural variability. Part of the change in indigenous plant communities came from the influx of exotic species and increase in weed biomass. Within freshwater wetlands, a large structural change also came from increasing biomass of the indigenous species raupō, swamp millet and purua grass (among others) leading to a decrease in evenness. Communities that are less even (i.e. have a less even distribution of biomass across species) tend to be less resilient to perturbations (Hong et al 2021).

Increasing distribution and dominance of raupō globally and in Aotearoa New Zealand has been linked with both human disturbance and nutrient enrichment of wetlands (Li et al 2024). The majority of wetlands in Tāmaki Makaurau have been disturbed to some extent. Analysis of abiotic measurements suggested that most wetlands in the TBMP were nitrogen-limited, and that raupō was increasing most in biomass in wetlands with elevated nitrogen relative to carbon. Increasing raupō biomass represents a threat to wider biodiversity (areas of high raupō biomass were associated with much lower plant species richness). Raupō also has high cultural value to tangata whenua and its rapid growth will remove nutrients from the water during the growing season, protecting downstream water quality. Without harvesting however, a large proportion of these nutrients will be returned to wetlands during decomposition.

According to the WCI, 80% of wetlands were in excellent or good condition. This assessment however, masks widespread problems since introduced plants were ubiquitous, affecting both canopy and understory layers, and only nine sites showed minimal predator impacts, primarily in Regional Parks such as Tāwharanui and Shakespear with high conservation management. Sites with high predator impacts were predominately on private land, and many were in the Kaipara ecological district. Water table modifications were also particularly notable in the Kaipara ecological district, where sandy substrates and pine plantations can contribute to wetland drying. Sixteen wetlands had lost more than 50% of their presumed original area, and 24 showed signs of high nutrient enrichment.

The WPI highlights the anthropogenic pressures wetlands face in Tāmaki Makaurau, where 88% of wetlands face moderate to high anthropogenic pressure. Only 12% qualified as "low pressure" sites, predominantly in indigenous landscapes on publicly managed land including seven Regional Parks. High pressure wetlands were characterised by extensive catchment modification (>75% altered hydrology), dominance of introduced vegetation, multiple invasive plant species, and evidence of water quality decline through sedimentation and nutrient enrichment. These were concentrated in rural, urban, and exotic forestry landscapes, with the majority under private ownership. Over the monitoring period, pressure from invasive plants increased significantly, as did catchment hydrological modifications.

The WEI showed 40% of wetlands had good edge condition, while 52% were moderate and 8% poor. Poor edge condition was characterised by inadequate buffers, stock access, drainage, and exotic plant dominance. Wetlands with poor edge condition were predominately in rural landscapes and were skewed towards private land.

Results from all three indices suggest that wetlands with good wetland and edge condition and low pressure were more common on public land and in Regional Parks. This highlights the importance of active management at both the wetland-scale, with improved pest plant and animal control, and at a catchment-scale with improved hydrological, sediment and nutrient control. The beauty of the indices is that they show what management activities are required to improve wetland condition. The turnover in indigenous species composition and structure in a relatively short period (15 years) suggests that wetlands would be responsive to management.

Anthropogenic pressures including from habitat loss, drainage, exotic and pest plant, pest animals, nutrient enrichment and water quality declines will have a very real impact on vulnerable plant species occurring in wetlands. Of the 50 nationally or regionally Threatened, At Risk or Data Deficient species recorded in wetland plots over the 15 years of monitoring, only eight species showed small increases in biomass, 11 species showed small declines and remaining species were only detected in one rotation, indicating their high vulnerability to local extinction. Fifty-six per cent of Threatened, At Risk or Data Deficient species require wetland habitat to persist.

Preliminary use of the modified Prevalence Index (PI_{mod}) indicated no systematic regional shift in wetland hydrology, but further work is required to test and verify this tool. Of specific interest is understanding impacts of stormwater treatment on wetlands in urban areas and wetland hydrology in the Kaipara ecological district. The documented site-specific changes in wetness highlight the importance of catchment-scale management for maintaining wetland hydrological integrity. The relationship between forest regeneration and increased wetland wetness at sites like Granny's Bay demonstrates the potential for forest ecosystem restoration to provide co-benefits for wetlands.

4.2 Terrestrial Biodiversity Monitoring Programme (TBMP)

The Terrestrial Biodiversity Monitoring Programme (TBMP) wetland plot network provides long-term, systematically collected and quantitative data on wetland plant and bird composition, structure and function, and semi-quantitative assessments on wetland condition, pressure and edge condition. Analysis of TBMP data allows us to track wetland ecology and biodiversity regionally. The 15-year dataset reveals patterns that would not be apparent over shorter timeframes, and the combination of vegetation, index and abiotic parameter monitoring generates insights that individual monitoring approaches could not achieve. The five-year monitoring cycle appears to appropriately balance resource efficiency and temporal resolution for detecting ecological changes (e.g. community turnover) in these ecosystems.

The spatially stratified systematic sampling design provides broadly representative coverage of palustrine wetlands in Tāmaki Makaurau. Future analysis would benefit from separating palustrine and saline systems to improve the interpretability of palustrine data by removing the potentially confounding effects of fundamentally different ecosystems. Improved saline wetland monitoring would give us a better understanding of these ecosystems that represent 65% of wetland extent in Tāmaki Makaurau, provide an array of ecosystem services including protection against storm surge, carbon sequestration and biodiversity provision, and are vulnerable to different pressures (e.g. sea-level rise).

There have been recent improvements to the wetland plot protocol through the introduction of simple five-minute wasp counts and plant phenology monitoring. Invasive wasps reach huge densities in wetland systems and represent a major threat to indigenous invertebrate biodiversity (Beggs et al 2011, Lefort et al 2020a, Lefort et al 2020b). Plant phenology monitoring was introduced to the wetland plot protocol when we observed that plants were senescing earlier in the year making some species identification impossible. In response we moved our monitoring period from February – April, to January – March). Consistent monitoring of abiotic parameters enabled analysis of nutrient enrichment patterns. The value of these data will only increase over time with the ability to observe trends and set baseline values. It would be beneficial to have access to comparative data including more pristine sites such as that provided by the wetland database supported by Manaaki Whenua Landcare Research. Analysis of TBMP wetland data has revealed that work is required to verify wetland classifications, especially for wetland class (Johnson & Gerbeaux 2004).

Water quantity, or hydrology, is one of the compulsory values for wetland monitoring required by the NPS-FM, but hydrological instrumentation and maintenance are expensive. In this report we explore the use of a modified Prevalence Index (PI_{mod}) to track wetland hydrology using existing TBMP plot data, namely the plant species abundances measured in the 10 x 10m subplot and their associated wetland indicator status. Preliminary analyses were highly promising and given the relatively fast turnover in wetland plant communities over time (compared to forest ecosystems for example), the PI_{mod} could be fairly responsive to changes in hydrology. Further work is required however to optimise the use of the 10 x 10m plot data by experimenting with how existing plot data for herbaceous species is included and excluding species not rooted inside the plot, especially those exotic and pest plants that grow into the plot from more upland areas. Ideally, different plot methods would be field-tested simultaneously in a range of hydrological regimes and alongside hydrological monitoring to fully test this tool and set credible thresholds. A plant-based hydrology monitoring tool will be of benefit to many regional and district councils nationally.

The wetland condition, pressure and edge indices (WCI, WPI, WEI) provide a valuable tool to assess a wide range of parameters that can be used in data analysis and to prioritise management goals. The wetland condition and pressure indices are one of the few monitoring tools used nationally, and by several regional and district councils to describe and compare wetlands (Clarkson et al 2004). All three indices, however, suffer to varying extents from subjective scoring and inconsistent application of scores between remeasures. Furthermore, several sub-indicators proved difficult to assess reliably in the field. Within the TBMP, improvements can be made when training teams to ensure scoring is calibrated, that notes are recorded in the field to justify scores, and to provide previous scores for reference. Calibration of scoring also needs to happen nationally. In this report, several plot and abiotic parameters were used to assess or corroborate some sub-indicators but there is more work that could be done. Finally, thresholds for Excellent, Good, Moderate and Poor condition were set in an arbitrary manner and it was acknowledged that they may need revising (Clarkson 2015). As they are currently set, there is a risk the wetland condition index will create a false sense that wetland ecosystems are in good condition and do not require intervention.

5 References

Allen, W., McCarthy, J., Jolly, B., Planzer, S., Sprague, R., Richardson, S., Baker, C., Graham, E., Mahlum, S., Hickford, M., Smith, B., Crawford, R., McArthur, N., Beattie, A. (2024). Ecological effects of Cyclone Gabrielle. LC4549, Manaaki Whenua Landcare Research.

Atkinson, I.A.E. (1985). Derivation of vegetation mapping units for an ecological survey of Tongariro National Park, North Island, New Zealand. New Zealand Journal of Botany 23, 361-378.

Ausseil A-G.E., Kirschbaum M.U.F., Andrew R.M., McNeill S., Dymond J.R., Carswell F., Mason N.W.H. (2013). Climate regulation in New Zealand: contribution of natural and managed ecosystems. *In* Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

Ausseil A-G.E., Chadderton, W.L., Gerbeaux, P., Stephens, R.T.T., Leathwick, J.R. (2011). Applying systematic conservation planning principles to palustrine and inland saline wetlands of New Zealand. Freshwater Biology 56, 142-161.

Bates, D., Mächler, M., Bolker, B., Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67 (1), 1-48. doi:10.18637/jss.v067.i01.

Beggs, J.R., Brockerhoff, E.G., Corley, J.C., Kenis, M., Masciocchi, M., Muller, F., Rome, Q., Villemant, C. (2011). Ecological effects and management of invasive alien Vespidae. *Biocontrol* 56, 505-526.

Beresford R., Smith, G., Ganley, B., Campbell, R. (2019). Impacts of myrtle rust in New Zealand since its arrival in 2017. *New Zealand Garden Journal* 22 (2), 5-10.

Bird, S., Wilkinson, S., McGaughran, A. (2024). Wetland biodiversity in Aotearoa New Zealand: an eDNA perspective on exotic and non-exotic species. *New Zealand Journal of Zoology*. https://doi.org/10.1080/03014223.2024.2359685

Bishop, C., Landers, T.J., (2019). Climate change risk assessment for terrestrial species and ecosystems in the Auckland region. Research and Evaluation Unit (RIMU), Auckland Council.

Bodmin, K. (2010) Weeds. In Wetland Restoration: A handbook for New Zealand Freshwater Systems. Eds. M. Peters, B. Clarkson. Manaaki Whenua Press, Lincoln, NZ.

Brandt, A.J., Bellingham, P.J., Duncan, R.P., Etherington, T.R., Fridley, J.D., Howell, C.J., et al. (2021). Naturalised plants transform the composition and function of the New Zealand flora. *Biological Invasions* 23, 351-366.

Brooks, M., Bolker, B., Kristensen, K., Maechler, M., Magnusson, A., McGillyCuddy, M., Skaug, H., et al (2025). Package 'glmmTMB' Generalised linear mixed models using Template Model Builder. CRAN R-project. https://cran.r-project.org/web/packages/glmmTMB/glmmTMB.pdf

Burge, O.R., Clarkson, B.R., Bodmin, K.A., Bartlam, S., Robertson, H.A., Sukias, J.P.S., Tanner, C. (2019). Plant responses to nutrient addition and predictive ability of vegetation N:P ratio in an austral fen. *Freshwater Biology*. DOI: 10.1111/fwb.13452

Burge, O.R., Price, R., Wilmshurst, J.M., Blyth, J.M., Robertson, H.A. (2023). LiDAR reveals drains risk to wetlands have been underestimated. *New Zealand Journal of Ecology* 47, 3523.

Cassidy, N.G. (1972) Observations on nutrient deficiencies in kikuyu grass (*Pennisetum clandestinum*). Queensland Journal of Agricultural and Animal Science 29, 51-57.

Clarkson, B.R., Sorrell, B.K., Reeves, P.N., Champion, P.D., Partridge, T.R., Clarkson, B.D. (2004). Handbook for monitoring wetland condition. Coordinated monitoring of New Zealand wetlands. Manaaki Whenua Landcare Research, Hamilton, New Zealand. doi:10.7931/J2Z60KZ3.

Clarkson, B.R. (2013). A vegetation tool for wetland delineation in New Zealand. Manaaki Whenua Landcare Research.

Clarkson, B.R., Ausseil, A.E., Gerbeaux, P. (2013). Wetland ecosystem services. *In* Dymond JR ed. Ecosystem services in New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand.

Clarkson, B.R., Fitzgerald, N.B., Overton, J.M. (2014). A methodology for monitoring Bay of Plenty wetlands. Manaaki Whenua Landcare Research.

Clarkson, B. Overton, J., Ausseil, A.-G., Robertson, H. (2015). Towards quantitative limits to maintain the ecological integrity of freshwater wetlands: Interim report. Department of Conservation.

Clarkson, B., Bartlam, S. (2017). State of the Environment monitoring of Hawkes Bay wetlands: Tukituki catchment. Prepared for Hawkes Bay Regional Council, HBRC Report No. RM 17-06, Plan No 4928. Manaaki Whenua Landcare Research, Hamilton, New Zealand.

Clarkson, B.R., Fitzgerald, N.B., Champion, P.D., Forester, L., Rance, B.D. (2021). New Zealand Wetland Plant List 2021. Prepared by Manaaki Whenua Landcare Research for Hawkes Bay Regional Council. Contract Report: LC3975. https://datastore.landcareresearch.co.nz/dataset/nz-wetland-plant-indicator-status-ratings-2021

Cooke, J.G., Cooper, A.B., Clunie, N.M.U. (1990). Changes in the water, soil and vegetation of a wetland after a decade of receiving a sewage effluent. New Zealand Journal of Ecology 14, 37-47.

de Lange, P.J., Rolfe, J.R., Barkla, J.W., Courtney, S.P., Champion, P.D., Perrie, L.R., Beadel, S.M., Ford, K.A., Breitwieser, I., Schönberger, I., Hindmarsh-Walls, R., Heenan, P.B., Ladley, K. (2017). Conservation status of New Zealand indigenous vascular plants, 2017. *New Zealand Threat Classification Series 22*. 82 p.

de Lange, P.J., Gosden, J., Courtney, S.P., Fergus, A.J., Barkla, J.W., Beadel, S.M., Champion, P.D., Hidmarsh-Walls, R., Makan, T., Michel, P. (2024). Conservation status of vascular plants in Aotearoa New Zealand, 2023. *New Zealand Threat Classification Series 43*. 105 p.

Denyer K., Baber, M., Clarkson, B.R. (2011). Auckland Regional Wetland Biodiversity Monitoring Programme: Field Protocol for Tier I Wetland Condition Monitoring. Amended 2011. Auckland Regional Council.

Denyer, K., Peters, M. (2014). WETMAK: A wetland monitoring and assessment kit for community groups. NZ Landcare Trust, Hamilton, NZ.

Denyer, K., Peters, M. (2020). The root causes of wetland loss in New Zealand: An analysis of public policies and processes. National Wetland Trust of New Zealand.

Dymond, J.R., Sabetizade, M., Newsome, P.F., Harmsworth, G.R., Ausseil, A.-G. (2021). Revised extent of wetlands in New Zealand. New Zealand Journal of Ecology 45, 3444.

Easdale, T, Burge, O, Wiser, S., Richardson, S. (2022). Carbon assessment of wetland vegetation. Manaaki Whenua Landcare Research. Contract report LC4173 for Ministry for the Environment.

Fenemor, A., Samarasinghe, O. (2020). Riparian setback distances from water bodies for high-risk land uses and activities. Tasman District Council Envirolink Grant 2057-TSDC167. Manaaki Whenua Landcare Research LC3832.

Fessardi, M., Landers, T., Lawrence, G., Meiforth, J., Ludbrook, M.R., McMurtry, J. (2025). Diversity, abundance and distribution of terrestrial birds in Tāmaki Makaurau / Auckland 2009-2024. State of the environment reporting. Auckland Council technical Report, TR2025/17.

Goodrich, J., Robertson, H. (2024). Technical note: wetland carbon abatement. Ministry for the Environment. 4.-FINAL-Wetland-carbon-abatement_technical-note-25-January-2024.pdf

Graeme, M., Kendal, H. (2001). Saltwater paspalum (Paspalum vaginatum) – a weed review. Environment Waikato Technical Report 2001/18.

Griffiths, G.J.K. and Lawrence, G. (2021) Wetlands in Tāmaki Makaurau. Evidence to the Auckland Council Planning Committee, October 2021.

Griffiths, G.J.K., Lawrence, L. (2025). Forest ecological integrity in Tāmaki Makaurau 2009-2024. State of the Environment reporting. Auckland Council Technical Report, TR2025/22.

Guan, Y., Jin, S., Zhang, Z., Chen, S., Chen, Y., Liu, S., Fan, M., Ding, Y., Yuan, X. (2025). A comprehensive review of climate warming and carbon dynamics in wetland ecosystems. Discover Sustainability 6, 672.

Helfter, C., Gondwe, M., Murray-Hudson, M., Makati, A., Sikiba, U. (2021). From sink to source: high inter-annual variability in the carbon budget of a Southern African wetland. *Philosophical Transactions A*, https://doi.org/10.6084/m9.figshare.c.5679608

Holdaway, R.J., Easdale, T.A., Carswell, F.E., Richardson, S.J., Pelzer, D.A., Mason, N.W.H., Brandon, A.M., Coomes, D.A. (2017). Nationally representative plot network reveals contrasting drivers of net biomass change in secondary and old-growth forests. Ecosystems 20, 944-959.

Hong, P., Schmid, B., Laender, F.D., Eisenhauer, N., Zhang, X., Chen, H., Craven, D., Boeck, H.J.D., et al (2021). Biodiversity promotes ecosystem functioning despite environmental change. Ecology Letters 25, 555-569.

Johnson, P., Brooke, P. (1998) Wetland Plants in New Zealand. Manaaki Whenua Press, Lincoln, Canterbury, New Zealand.

Johnson, P., Gerbeaux, P. (2004). Wetland types in New Zealand. Department of Conservation, Wellington, NZ.

Koerselman W, Meuleman AFM 1996. The vegetation N:P ratio: a new tool to detect the nature of nutrient limitation. Journal of Applied Ecology 33: 1441–1450.

Landers, T.J. Allen, H., Bishop, C.D., Griffiths, G.J.K., Khin, J., Lawrence, G., Ludbrook, M.R. (2021). Diversity, abundance and distribution of birds in Tāmaki Makaurau / Auckland 2009-2019. Auckland Council technical report, TR2021/08.

Lawrence, G, Bishop, C. (2017). Remapping the extent of Auckland's wetlands: methods and summary. Auckland Council technical report 2017/024.

Lefort, M-C., Beggs, J.R., Glare, T.R., Saunders, T.E., Doyle, E.J., Boyer, S. (2020a). A molecular approach to study Hymenoptera diets using wasp nests. *NeoBiota* 63, 57-79.

Lefort, M-C., Beggs, J.R., Glare, T.R., Doyle, E.J., Saunders, T.E., Boyer, S. (2020b). A molecular approach to study Hymenoptera diets using polistine wasps. BioRxiv doi: https://doi.org/10.1101/2020.04.06.024422

Li, X., Newnham, R., Vandergoes, M.J. et al (2024). Insights into the natural and cultural history of *Typha orientalis* (Raupō) in Aotearoa New Zealand. PLOS Water 3, e0000240.

Lindsay, H., Wild, C., Byers, S. (2009). Auckland Protection Strategy: A report to the Nature Heritage Fund Committee. Nature Heritage Fund, Wellington, New Zealand.

Macinnis-Ng, C., Mcintosh, A.R., Monks, J.M., Waipara, N., White, R.S., Boudjelas, S., et al. (2021). Climate-change impacts exacerbate conservation threats in island systems: New Zealand as a case study. *Frontiers in Ecology and the Environment*, doi:10.1002/fee.2285.

McGlone, M.S., Duncan, R.P. and Heenan, P.B. (2001). Endemism, species selection and the origin and distribution of the vascular plant flora of New Zealand. Journal of Biogeography 28, 199-216.

Ministry for the Environment (2022). *Wetland delineation protocols*. Wellington: Ministry for the Environment.

Ministry for the Environment. (2025). Package 3: Freshwater – Discussion document. Wellington, New Zealand: Ministry for the Environment. https://environment.govt.nz/assets/publications/RMA/package-3-freshwater-discussion-document.pdf

Ministry for the Environment. (2025). *Interim Regulatory Impact Statement: Simplifying the wetland provisions in the NPS-FM and NES-F*. Wellington, New Zealand: Ministry for the Environment. https://environment.govt.nz/assets/Interim-RIS-Simplifying-the-wetland-provisions-in-the-NPS-Freshwater-Management-and-NES-Freshwater.pdf

Oksanen, J., Simpson, G., Blanchet, F., Kindt, R., Legendre, P., Minchin, P., O'Hara, R., Solymos, P., Stevens, M., Szoecs, E., Wagner, H., Barbour, M., Bedward, M., Bolker, B., Borcard, D., Carvalho, G., Chirico, M., De Caceres, M., Durand, S., Evangelista, H., FitzJohn, R., Friendly, M., Furneaux, B., Hannigan, G., Hill, M., Lahti, L., McGlinn, D., Ouellette, M., Ribeiro Cunha, E., Smith, T., Stier, A., Ter Braak, C., Weedon, J. (2022). _vegan: Community Ecology Package_. R package version 2.6-4, https://CRAN.R-project.org/package=vegan

Parkyn, S., Shaw, W., Eades, P. (2000). Review of information on riparian buffer widths necessary to support sustainable vegetation and meet aquatic functions. NIWA, Hamilton, NZ.

Peres-Neto, P.R., Jackson, D.A. (2001). How Well Do Multivariate Data Sets Match? The Advantages of a Procrustean Superimposition Approach over the Mantel Test. *Oecologia* 129, 169-178.

Peters, M., Clarkson, B. (2010). Wetland restoration: a handbook for New Zealand freshwater systems Lincoln, N.Z. : Manaaki Whenua Press.

Petrescu, A.M.R., Lohila, A., Tuovinen, J-P., Cescatti, A. (2015). The uncertain climate footprint of wetlands under human pressure. PNAS 112, 4594-4599.

Prickett, M., Joy, M.K. (2024). Aotearoa New Zealand's new Government proposal to remove hard won protection for waterways will worsen the country's freshwater crisis. Inland Waters 14, 37-48.

R Core Team (2022). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org

Richardson, S. J., Clayton, R., Rance, B. D., Broadbent, H., McGlone, M. S., Wilmshurst, J. M. (2014). Small wetlands are critical for safeguarding rare and threatened plant species. Applied Vegetation Science 18, 230-241.

Schmack, J. M., Schleuning, M., Ward, D. F., and Beggs, J. R. (2020). Biogeography and anthropogenic impact shape the success of invasive wasps on New Zealand's offshore islands. *Diversity and Distributions*, *26*(4), 441-452. https://doi.org/10.1111/ddi.13021

Simpkins, E., Woolly, J., de Lange, P., Kilgour, C., Cameron, E., Melzer, S. (2022). Conservation status of vascular plant species in Tāmaki Makaurau / Auckland. Auckland Council technical report, TR2022/19.

Singers, N.J.D, Rogers, G.M. (2014). A classification of New Zealand's terrestrial ecosystems. Science for Conservation 325. Department of Conservation.

Singers, N., Osborne, B., Lovegrove, T., Jamieson, A., Boow, J., Sawyer, J., Hill, K., Andrews, J., Hill, S., Webb, C. (2017). Indigenous terrestrial and wetland ecosystems of Auckland. Auckland Council.

Sorrel, B. (2012). Nutrients. In Wetland restoration: a handbook for New Zealand freshwater systems. Eds Monica Peters, Beverley Clarkson. Manaaki Whenua Press, Lincoln, N.Z.

Tan, L., Ge, Z., Ji, Y., Lai, D. Y. F., Temmerman, S., Li, S., Li, X., Tang, J. (2022). Land use and land cover changes in coastal and inland wetlands cause soil carbon and nitrogen loss. Global Ecology and Biogeography 31, https://onlinelibrary.wiley.com/doi/10.1111/geb.13597

Taura, Y., Van Schravendijk-Goodman, C., Clarkson, B. (2017). Te reo o te repo. The voice of the wetland. Connections, understandings and learnings for the restoration of our wetlands. Manaaki Whenua Landcare research and Waikato Raupatu River Trust.

Thompson-Morrison, H., McNally, S. (2024). Soil carbon. *In:* Lohrer, D., et al. *Information Stocktakes of Fifty-Five Environmental Attributes across Air, Soil, Terrestrial, Freshwater, Estuaries and Coastal Waters Domains*. Prepared by NIWA, Manaaki Whenua Landcare Research, Cawthron Institute, and Environet Limited for the Ministry for the Environment. NIWA report no. 2024216HN (project MFE24203, June 2024). [https://environment.govt.nz/publications/information-stocktakes-of-fifty-five-environmental-attributes]

Russi, D., ten Brink, P., Farmer, A., Badura, T., Coates, D., Förster, J., Kumar, R. and Davidson, N. (2013). The Economics of Ecosystems and Biodiversity for Water and Wetlands. IEEP, London and Brussels, Ramsar Secretariat, Gland.

Tomer M, Tanner CC, Howard-Williams C (2009). Discussing wetlands, agriculture, and ecosystem services: perspectives from two countries. Wetlands Science and Practice 26: 26-29.

Trang, N.T.D. (2022). Potential use of *Scirpus littoralis* and *Typha orientalis* for nitrogen and phosphorus removal from intensive whiteleg shrimp wastewater. *Agriculture and Rural Development* 2, 72-104.

U.S. EPA. (2002). Methods for Evaluating Wetland Condition: Vegetation-Based Indicators of Wetland Nutrient Enrichment. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA-822-R-02-024.

Wang, Y., Wang, J., Zhao, X., Song, X., Gong, J. (2016). The inhibition and adaptability of four wetland plant species to high concentration ammonia wastewater and nitrogen removal efficiency in constructed wetlands. *Bioresource Technology* 202, 198-205.

Wilby, N.J., Pulford, I.D., Flowers, T.H. (2001) Tissue nutrient signatures predict herbaceous wetland community responses to nutrient availabiliy. *New Phytologist* 152, 463-481.

6 Appendices

6.1 Appendix 1. Wetland indicator status of TBMP species

Taxa	NVSCode	WLStatus	WLStatusSource
Acacia longifolia	ACALON	UPL	default UPL
Acacia mearnsii	ACAMEA	UPL	Clarkson et al 2021
Acaena agnipila	ACAAGN	UPL	default UPL
Acaena anserinifolia	ACAANS	FACU	Clarkson et al 2021
Acaena novae-zelandiae	ACANOV	FACU	Clarkson et al 2021
Acaena pallida	ACAPAL	UPL	default UPL
Achillea millefolium	ACHMIL	FACU	Clarkson et al 2021
Adiantum hispidulum	ADIHIS	FACU	Auckland Council 2022
Agathis australis	AGAAUS	UPL	Auckland Council
Ageratina adenophora	AGEADE	FAC	Clarkson et al 2021
Ageratina riparia	AGERIP	UPL	Clarkson et al 2021
Agrostis capillaris	AGRCAP	FACU	Clarkson et al 2021
Agrostis castellana	AGRCAS	UPL	default UPL
Agrostis stolonifera	AGRSTO	FACW	Clarkson et al 2021
Alectryon excelsus	ALEEXC	UPL	default UPL
Alisma plantago-aquatica	ALIPLA	OBL	Clarkson et al 2021
Allium triquetrum	ALLTRI	FAC	Clarkson et al 2021
Alnus glutinosa	ALNGLU	FACW	Clarkson et al 2021
Alocasia brisbanensis	ALOBRI	FACW	Auckland Council 2022
Alopecurus aequalis	ALOAEQ	FACW	Clarkson et al 2021
Alternanthera denticulata	ALTDEN	FACW	Clarkson et al 2021
Alternanthera nahui	ALTNAH	FACW	Clarkson et al 2021
Alternanthera philoxeroides	ALTPHI	FACW	Clarkson et al 2021
Amaranthus blitum subsp. oleraceus	AMABSO	FACU	Auckland Council
Amaranthus deflexus	AMADEF	UPL	default UPL
Anthoxanthum odoratum	ANTODO	FACU	Clarkson et al 2021
Apium prostratum	APIPRO	FAC	Clarkson et al 2021
Apodasmia similis	APOSIM	FACW	Clarkson et al 2021
Araujia sericifera	ARASER	UPL	default UPL
Archeria racemosa	ARCRAC	UPL	default UPL
Archontophoenix cunninghamiana	ARCCUN	UPL	default UPL
Aristea ecklonii	ARIECK	UPL	default UPL
Arrhenatherum elatius	ARRELA	FACU	USDA
Artemisia verlotiorum	ARTVER	UPL	default UPL
Asparagus asparagoides	ASPASP	FACU	Clarkson et al 2021
Asparagus scandens	ASPSCA	FACU	Clarkson et al 2021
Asplenium bulbiferum	ASPBUL	UPL	Clarkson et al 2021
Asplenium flaccidum	ASPFLA	UPL	Clarkson et al 2021
Asplenium oblongifolium	ASPOBL	UPL	Clarkson et al 2021
Asplenium polyodon	ASPPOL	UPL	Clarkson et al 2021
Astelia grandis	ASTGRA	OBL	Clarkson et al 2021
Astelia hastata	ASTHAS	UPL	Clarkson et al 2021
Astelia subulata	ASTSUB	OBL	Clarkson et al 2021
Atriplex patula	ATRPAT	FACW	USDA
Atriplex prostrata	ATRPRO	FACU	Clarkson et al 2021
Austroderia fulvida	AUSFUL	FAC	Clarkson et al 2021
Avicennia marina	AVIMAR	OBL	Clarkson et al 2021
Avicennia marina subsp. australasica	AVIMSA	OBL	Clarkson et al 2021
Axonopus fissifolius	AXOFIS	FACU	Clarkson et al 2021
Azolla filiculoides	AZOFIL	OBL	Auckland Council
Azolla pinnata	AZOPIN	OBL	Clarkson et al 2021
Azolla rubra	AZORUB	OBL	Clarkson et al 2021
Beilschmiedia tarairi	BEITAR	FACU	Auckland Council
Bellardia viscosa	BELVIS	FAC	Clarkson et al 2021

Taxa	NVSCode	WLStatus	WLStatusSource
Berberis glaucocarpa	BERGLA	FACU	Clarkson et al 2021
Bidens frondosa	BIDFRO	FACW	Clarkson et al 2021
Blechnum discolor	BLEDIS	FACU	Clarkson et al 2021
Blechnum filiforme	BLEFIL	FACU	Clarkson et al 2021
Blechnum fluviatile	BLEFLU	FACU	Clarkson et al 2021
Blechnum minus	BLEMIN	FACW	Clarkson et al 2021
Blechnum novae-zelandiae	BLENOV	FAC	Clarkson et al 2021
Blechnum parrisiae	BLEPAR	UPL	Clarkson et al 2021
Bolboschoenus caldwellii	BOLCAL	OBL	Clarkson et al 2021
Bolboschoenus fluviatilis	BOLFLU	OBL	Clarkson et al 2021
Bolboschoenus medianus	BOLMED	OBL	Clarkson et al 2021
Brachyglottis kirkii	BRAKIR	UPL	default UPL
Brassica rapa	BRARAP	UPL	default UPL
Briza minor	BRIMIN	FACW	USDA
Bromus catharticus	BROCAT	UPL	Clarkson et al 2021
Callitriche muelleri	CALMUE	FACW	Clarkson et al 2021
Callitriche stagnalis	CALSTA	OBL	Clarkson et al 2021
Calystegia sepium	CALSEP	FAC	Clarkson et al 2021
Calystegia sepium subsp. roseata	CALSSR	FAC	Clarkson et al 2021
Calystegia sepium subsp. sepium	CALSSS	FAC	Clarkson et al 2021
Calystegia sepium x silvatica	CALXSS	FAC	Clarkson et al 2021
Calystegia sepium x soldanella	CALSXS	FAC	Auckland Council
Calystegia sepium x tuguriorum	CALSXT	FACU	Auckland Council 2022
Calystegia silvatica	CALSIL	FACU	Clarkson et al 2021
Calystegia tuguriorum	CALTUG	FACU	Clarkson et al 2021
Cardamine dolichostyla	CARDLC	FAC	Clarkson et al 2021
Cardamine flexuosa	CARFLE	FAC	USDA
Cardamine forsteri	CARFRS	UPL	default UPL
Cardamine hirsuta	CARHIR	UPL	Auckland Council
Carex dissita	CARDIS	FAC	Clarkson et al 2021
Carex divisa	CARDVS	FAC	Clarkson et al 2021
Carex divulsa	CARDIV	FAC	Clarkson et al 2021
Carex fascicularis	CARFAS	OBL	Clarkson et al 2021
Carex flagellifera	CARFGL	FACU	Clarkson et al 2021
Carex geminata	CARGEM	FACW	Clarkson et al 2021
Carex lambertiana	CARLAM	FAC	Clarkson et al 2021
Carex leporina	CARLEP	FACW	Clarkson et al 2021
Carex lessoniana	CARLES	FACW	Clarkson et al 2021
Carex maorica	CARMAO	OBL	Clarkson et al 2021
Carex ochrosaccus	CAROCH	FAC	Clarkson et al 2021
Carex punctata	CARPUN	UPL	default UPL
Carex scoparia	CARSCO	FACW	Clarkson et al 2021
Carex secta	CARSEC	OBL	Clarkson et al 2021
Carex solandri	CARSOL	FAC	Clarkson et al 2021
Carex subdola	CARSUB	OBL	Clarkson et al 2021
Carex uncinata	CARUCN	FACU	Clarkson et al 2021
Carex virgata	CARVIR	FACW	Clarkson et al 2021
Carex vulpinoidea	CARVUL	OBL	Clarkson et al 2021
Carex zotovii	CARZOT	UPL	default UPL
Carmichaelia australis	CARAUS	FACU	Clarkson et al 2021
Carpodetus serratus	CARSER	FACU	Clarkson et al 2021
Cenchrus clandestinus	CENCLA	FACU	Clarkson et al 2021
Cenchrus purpurascens	CENPUP	UPL	default UPL
Centaurium erythraea	CENERY	FACU	Clarkson et al 2021

Taxa	NVSCode	WLStatus	WLStatusSource
Centella uniflora	CENUNI	FACW	Clarkson et al 2021
Cerastium fontanum	CERFON	FACU	Clarkson et al 2021
Cerastium fontanum subsp. vulgare	CERFSV	UPL	default UPL
Cerastium glomeratum	CERGLO	FACU	Clarkson et al 2021
Ceratophyllum demersum	CERDEM	OBL	Clarkson et al 2021
Cestrum nocturnum	CESNOC	UPL	USDA
Cirsium arvense	CIRARV	FACU	Clarkson et al 2021
Cirsium vulgare	CIRVUL	FACU	Clarkson et al 2021
Clematis forsteri	CLEFOR	UPL	default UPL
Clematis paniculata	CLEPAN	UPL	Clarkson et al 2021
Colocasia esculenta	COLESC	FACW	Clarkson et al 2021
Coprosma arborea	COPARB	UPL	default UPL
Coprosma areolata	COPARE	FACU	Clarkson et al 2021
Coprosma autumnalis	COPGRA	FACU	Clarkson et al 2021
Coprosma crassifolia	COPCRA	UPL	default UPL
Coprosma lucida	COPLUC	FACU	Clarkson et al 2021
Coprosma macrocarpa	COPMAC	UPL	Clarkson et al 2021
Coprosma macrocarpa subsp. minor	COPMSM	UPL	Auckland Council
Coprosma propinqua	COPPRO	FAC	Clarkson et al 2021
Coprosma propinqua var. propinqua	COPPVP	FAC	Clarkson et al 2021
Coprosma propinqua x robusta	COPPXR	FAC	Clarkson et al 2021
Coprosma repens	COPREP	UPL	default UPL
Coprosma rhamnoides	COPRHA	UPL	Clarkson et al 2021
Coprosma robusta	COPROB	FACU	Clarkson et al 2021
Coprosma tenuicaulis	COPTEC	FACW	Clarkson et al 2021
Cordyline australis	CORAUS	FAC	Clarkson et al 2021
Cordyline banksii	CORBAN	UPL	Clarkson et al 2021
Coriaria arborea	CORARB	UPL	Clarkson et al 2021
Corokia cotoneaster	CORCOT	UPL	Clarkson et al 2021
Cortaderia jubata	CORJUB	UPL	Clarkson et al 2021
Cortaderia selloana	CORSEL	FAC	Clarkson et al 2021
Corybas macranthus	CORMAC	FACW	Clarkson et al 2021
Corynocarpus laevigatus	CORLAE	FACU	Clarkson et al 2021
Cotula australis	COTAUS	FAC	USDA
Cotula coronopifolia	COTCOR	FACW	Clarkson et al 2021
Crataegus monogyna	CRAMON	FACU	Clarkson et al 2021
Crepis capillaris	CRECAP	FACU	Clarkson et al 2021
Crocosmia xcrocosmiiflora	CROXCR	FACU	Auckland Council
Cyathea dealbata	CYADEA	UPL	Clarkson et al 2021
Cyathea medullaris	CYAMED	FACU	Clarkson et al 2021
Cyathea smithii	CYASMI	FACU	Clarkson et al 2021
Cyclosorus interruptus	CYCINT	OBL	Clarkson et al 2021
Cymbalaria muralis	CYMMUR	UPL	default UPL
Cynodon dactylon	CYNDAC	FACU	Clarkson et al 2021
Cynosurus cristatus	CYNCRI	UPL	Clarkson et al 2021
Cyperus brevifolius	CYPBRE	FACW	Clarkson et al 2021
Cyperus congestus	CYPCON	FAC	Clarkson et al 2021
Cyperus eragrostis	CYPERA	FACW	Clarkson et al 2021
Cyperus sanguinolentus	CYPSAN	FACW	Clarkson et al 2021
Cyperus ustulatus	CYPUST	FACW	Clarkson et al 2021
Dacrycarpus dacrydioides	DACDAC	FAC	Clarkson et al 2021
Dacrydium cupressinum	DACCUP	FACU	Clarkson et al 2021
Dactylis glomerata	DACGLO	FACU	Clarkson et al 2021
Daucus carota	DAUCAR	UPL	default UPL

Taxa	NVSCode	WLStatus	WLStatusSource
Delairea odorata	DELODO	FACU	USDA
Deparia petersenii	DEPPET	FAC	Clarkson et al 2021
Deparia petersenii subsp. congrua	DEPPSC	FAC	Clarkson et al 2021
Dianella haematica	DIAHAE	FACW	Clarkson et al 2021
Dianella nigra	DIANIG	UPL	Clarkson et al 2021
Dicksonia squarrosa	DICSQU	FACU	Clarkson et al 2021
Didymocheton spectabilis	DIDSPE	UPL	default UPL
Digitalis purpurea	DIGPUR	UPL	Clarkson et al 2021
Digitaria aequiglumis	DIGAEQ	UPL	default UPL
Digitaria sanguinalis	DIGSAN	FACU	Clarkson et al 2021
Diplazium australe	DIPAUS	FACU	Clarkson et al 2021
Dracaena draco	DRADRA	UPL	default UPL
Ehrharta erecta	EHRERE	UPL	default UPL
Elatostema rugosum	ELARUG	FACW	Auckland Council 2022
Eleocharis acuta	ELEACU	OBL	Clarkson et al 2021
Eleocharis gracilis	ELEGRA	OBL	Clarkson et al 2021
Eleocharis pusilla	ELEPUS	OBL	Clarkson et al 2021
Eleocharis sphacelata	ELESPH	OBL	Clarkson et al 2021
Elytrigia repens	ELYREP	FACU	Clarkson et al 2021
Empodisma minus	EMPMIN	OBL	Clarkson et al 2021
Empodisma robustum	EMPROB	OBL	Clarkson et al 2021
Entolasia marginata	ENTMAR	UPL	default UPL
Epilobium billardiereanum subsp. cinereum	EPIBSC	UPL	Clarkson et al 2021
Epilobium chionanthum	EPICHI	OBL	Clarkson et al 2021
Epilobium ciliatum	EPICIL	FAC	Clarkson et al 2021
Epilobium pallidiflorum	EPIPAL	OBL	Clarkson et al 2021
Epilobium rotundifolium	EPIROT	FACW	Auckland Council
Eragrostis brownii	ERABRO	UPL	default UPL
Erechtites hieraciifolius	EREHIE	FAC	Clarkson et al 2021
Erechtites valerianifolius	EREVAL	UPL	Clarkson et al 2021
Erica lusitanica	ERILUS	FACU	Clarkson et al 2021
Erigeron canadensis	ERICAN	FACU	Clarkson et al 2021
Erigeron sumatrensis	ERISUM	FACU	Clarkson et al 2021
Erodium moschatum	EROMOS	UPL	default UPL
Erythranthe moschata	ERYMOS	OBL	Clarkson et al 2021
Erythrina xsykesii	ERYXSY	UPL	Auckland Council
Euchiton audax	EUCAUD	FACU	Clarkson et al 2021
Euchiton japonicus	EUCJAP	FAC	Clarkson et al 2021
Euphorbia peplus	EUPPEP	UPL	default UPL
Ficinia nodosa	FICNOD	FACU	Clarkson et al 2021
Freycinetia banksii	FREBAN	FACU	Clarkson et al 2021
Fuchsia excorticata	FUCEXC	FACU	Clarkson et al 2021
Gahnia xanthocarpa	GAHXAN	FAC	Clarkson et al 2021
Galium aparine	GALAPA	FACU	Clarkson et al 2021
Galium divaricatum	GALDIV	FACU	Auckland Council
Galium palustre	GALPAL	OBL	Clarkson et al 2021
Galium propinquum	GALPRO	FACU	Clarkson et al 2021
Galium trilobum	GALTRI	FACU	Clarkson et al 2021
Gamochaeta coarctata	GAMAME	FACU	Clarkson et al 2021
Gamochaeta purpurea	GAMPUR	FACU	USDA
Gamochaeta simplicicaulis	GAMSIM	UPL	default UPL
Geniostoma ligustrifolium var. ligustrifolium	GENLVL	FACU	Clarkson et al 2021
Geranium robertianum	GERROB	FACU	USDA
Gladiolus undulatus	GLAUND	UPL	Clarkson et al 2021

Taxa	NVSCode	WLStatus	WLStatusSource
Gleichenia dicarpa	GLEDIC	FACW	Clarkson et al 2021
Gleichenia microphylla	GLEMIC	FAC	Clarkson et al 2021
Glossostigma elatinoides	GLOELA	OBL	Clarkson et al 2021
Glyceria declinata	GLYDEC	OBL	Clarkson et al 2021
Glyceria maxima	GLYMAX	OBL	Clarkson et al 2021
Gonocarpus micranthus	GONMIC	FAC	Clarkson et al 2021
Goodenia radicans	GOORAD	FACW	Clarkson et al 2021
Haloragis erecta	HALERE	FACU	Clarkson et al 2021
Haloragis erecta subsp. erecta	HALESE	FACU	Clarkson et al 2021
Hedera helix	HEDHEL	UPL	default UPL
Hedycarya arborea	HEDARB	UPL	Clarkson et al 2021
Hedychium gardnerianum	HEDGAR	FACW	USDA
Helminthotheca echioides	HELECH	UPL	Clarkson et al 2021
Helosciadium nodiflorum	HELNOD	OBL	Clarkson et al 2021
Hemarthria uncinata	HEMUNC	FACU	Auckland Council
Hesperocyparis macrocarpa	HESMAC	UPL	default UPL
Histiopteris incisa	HISINC	FAC	Clarkson et al 2021
Hiya distans	HIYDIS	FAC	Clarkson et al 2021
Hoheria populnea	HOHPOP	UPL	default UPL
Holcus lanatus	HOLLAN	FAC	Clarkson et al 2021
Homalanthus populifolius	HOMPOP	UPL	default UPL
Hydrocotyle heteromeria	HYDHET	FACU	Clarkson et al 2021
Hydrocotyle moschata	HYDMOS	FAC	Clarkson et al 2021
Hydrocotyle novae-zeelandiae	HYDNOV	FAC	Clarkson et al 2021
Hydrocotyle pterocarpa	HYDPTE	OBL	Clarkson et al 2021
Hypericum androsaemum	HYPAND	UPL	default UPL
Hypericum humifusum	HYPHUM	FAC	Clarkson et al 2021
Hypericum japonicum	HYPJAP	OBL	Clarkson et al 2021
Hypericum mutilum	HYPMUT	FACW	Clarkson et al 2021
Hypericum pusillum	HYPPUS	OBL	Clarkson et al 2021
Hypochaeris radicata	HYPRAD	FACU	Clarkson et al 2021
Hypolepis ambigua	HYPAMB	UPL	Clarkson et al 2021
Ipomoea indica	IPOIND	FAC	USDA
Iris pseudacorus	IRIPSE	OBL	Clarkson et al 2021
Isachne globosa	ISAGLO	OBL	Clarkson et al 2021
Isolepis cernua	ISOCER	OBL	Clarkson et al 2021
Isolepis distigmatosa	ISODIS	OBL	Clarkson et al 2021
Isolepis inundata	ISOINU	OBL	Clarkson et al 2021
Isolepis prolifera	ISOPRO	OBL	Clarkson et al 2021
Isolepis reticularis	ISORET	FACW	Clarkson et al 2021
Isolepis sepulcralis	ISOSEP	FAC	Clarkson et al 2021
Jacobaea vulgaris	JACVUL	FACU	Clarkson et al 2021
Juncus acuminatus	JUNACU	OBL	Clarkson et al 2021
Juncus acutiflorus	JUNACT	FACW	Clarkson et al 2021
Juncus acutus	JUNACS	FACW	Clarkson et al 2021
Juncus articulatus	JUNART	FACW	Clarkson et al 2021
Juncus australis	JUNAUS	FACW	Clarkson et al 2021
Juncus bufonius	JUNBUF	FACW	Clarkson et al 2021
Juncus bulbosus	JUNBUL	OBL	Clarkson et al 2021
Juncus canadensis	JUNCAN	OBL	Clarkson et al 2021
Juncus edgariae	JUNEDG	FACW	Clarkson et al 2021
Juncus effusus	JUNEFF	FACW	Clarkson et al 2021
Juncus fockei	JUNFOC	OBL	Clarkson et al 2021
Juncus kraussii	JUNKRA	FACW	Clarkson et al 2021

Taxa	NVSCode	WLStatus	WLStatusSource
Juncus kraussii subsp. australiensis	JUNKSA	FACW	Clarkson et al 2021
Juncus microcephalus	JUNMIC	FACW	Clarkson et al 2021
Juncus pallidus	JUNPAL	FACW	Clarkson et al 2021
Juncus pauciflorus	JUNPAU	FACW	Clarkson et al 2021
Juncus planifolius	JUNPLA	FACW	Clarkson et al 2021
Juncus prismatocarpus	JUNPRI	FACW	Clarkson et al 2021
Juncus procerus	JUNPRO	FACW	Clarkson et al 2021
Juncus sarophorus	JUNSAR	FACW	Clarkson et al 2021
Juncus sonderianus	JUNSON	FACW	Clarkson et al 2021
Juncus tenuis subsp. dichotomus	JUNTSD	FACW	Clarkson et al 2021
Juncus tenuis subsp. tenuis	JUNTST	FACU	Clarkson et al 2021
Juncus usitatus	JUNUSI	FACW	Clarkson et al 2021
Knightia excelsa	KNIEXC	UPL	Clarkson et al 2021
Kunzea ericoides	KUNERI	FACU	Clarkson et al 2021
Kunzea robusta	KUNERI	FACU	Clarkson et al 2021
Lachnagrostis filiformis	LACFIL	FACW	Clarkson et al 2021
Lachnagrostis littoralis	LACLIT	FACU	Auckland Council
Lamium purpureum	LAMPUR	UPL	default UPL
Landoltia punctata	LANPUN	OBL	Clarkson et al 2021
Lapsana communis	LAPCOM	FACU	USDA
Lastreopsis hispida	LASHIS	FACU	Auckland Council
Laurelia novae-zelandiae	LAUNOV	FAC	Clarkson et al 2021
Lecanopteris pustulata	LECPUS	UPL	Clarkson et al 2021
Lecanopteris scandens	LECSCA	UPL	Clarkson et al 2021
Lemna disperma	LEMDIS	OBL	Clarkson et al 2021
Lemna minor	LEMMIN	OBL	Clarkson et al 2021
Leontodon saxatilis	LEOSAX	FAC	Clarkson et al 2021
Leontodon taraxacoides	LEOSAX	FAC	Clarkson et al 2021
Leptecophylla juniperina	LEPJUN	UPL	default UPL
Leptospermum scoparium	LEPSCO	FAC	Clarkson et al 2021
Leucanthemum vulgare	LEUVUL	UPL	USDA
Leucopogon fasciculatus	LEUFAS	FACU	Clarkson et al 2021
Leycesteria formosa	LEYFOR	FACU	Clarkson et al 2021
Ligustrum lucidum	LIGLUC	FAC	USDA
Ligustrum sinense	LIGSIN	FACU	Clarkson et al 2021
Lilaeopsis novae-zelandiae	LILNOV	OBL	Clarkson et al 2021
Liquidambar styraciflua	LIQSTY	FAC	USDA
Lobelia anceps	LOBANC	FACW	Clarkson et al 2021
Lobelia angulata	LOBANG	FAC	Clarkson et al 2021
Lolium arundinaceum	LOLARU	FAC	Clarkson et al 2021
Lolium perenne	LOLPER	FACU	Clarkson et al 2021
Lonicera japonica	LONJAP	FACU	Clarkson et al 2021
Lotus angustissimus	LOTANG	FACU	Auckland Council
Lotus pedunculatus	LOTPED	FAC	Clarkson et al 2021
Lotus suaveolens	LOTSBF	FACU	Auckland Council
Ludwigia palustris	LUDPAL	OBL	Clarkson et al 2021
Ludwigia peploides	LUDPEP	OBL	Clarkson et al 2021
Lycopodium volubile	LYCVOL	FACU	Clarkson et al 2021
Lycopus europaeus	LYCEUR	OBL	Clarkson et al 2021
Lysimachia arvensis	LYSARV	FACU	Clarkson et al 2021
Lythrum hyssopifolia	LYTHYS	FACW	Clarkson et al 2021
Machaerina arthrophylla	MACART	OBL	Clarkson et al 2021
Machaerina articulata	MACATC	OBL	Clarkson et al 2021
Machaerina juncea	MACJUN	FACW	Clarkson et al 2021

Taxa	NVSCode	WLStatus	WLStatusSource
Machaerina rubiginosa	MACRUB	OBL	Clarkson et al 2021
Machaerina sinclairii	MACSIN	OBL	Clarkson et al 2021
Machaerina tenax	MACTEN	FACW	Clarkson et al 2021
Machaerina teretifolia	MACTER	FACW	Clarkson et al 2021
Medicago lupulina	MEDLUP	FACU	USDA
Melicytus macrophyllus	MELMAC	UPL	default UPL
Melicytus ramiflorus	MELRAM	FACU	Clarkson et al 2021
Mentha pulegium	MENPUL	FAC	Clarkson et al 2021
Mentha spicata	MENSPI	FAC	Clarkson et al 2021
Mentha xpiperita	MENXPI	FACW	Clarkson et al 2021
Metrosideros diffusa	METDIF	FACU	Clarkson et al 2021
Metrosideros excelsa	METEXC	UPL	Clarkson et al 2021
Metrosideros fulgens	METFUL	FACU	Auckland Council
Microlaena stipoides	MICSTI	FACU	Clarkson et al 2021
Modiola caroliniana	MODCAR	FACU	USDA
Muehlenbeckia australis	MUEAUS	FACU	Clarkson et al 2021
Muehlenbeckia complexa	MUECOM	FACU	Clarkson et al 2021
Myosotis arvensis	MYOARV	FACU	Clarkson et al 2021
Myosotis laxa	MYOLAX	OBL	Clarkson et al 2021
Myriophyllum aquaticum	MYRAQU	OBL	Clarkson et al 2021
Myriophyllum propinquum	MYRPRO	OBL	Clarkson et al 2021
Myriophyllum robustum	MYRROB	OBL	Clarkson et al 2021
Myrsine australis	MYRAUS	FACU	Clarkson et al 2021
Nasturtium microphyllum	NASMIC	OBL	Clarkson et al 2021
Nasturtium officinale	NASOFF	OBL	Clarkson et al 2021
Nertera depressa	NERDEP	FACU	Clarkson et al 2021
Nertera dichondrifolia	NERDIC	FACU	Auckland Council
Nertera scapanioides	NERSCA	OBL	Clarkson et al 2021
Nestegis cunninghamii	NOTCNN	UPL	default UPL
Oenanthe pimpinelloides	OENPIM	FACU	Auckland Council
Olearia rani	OLERAN	UPL	Auckland Council
Olearia solandri	OLESOL	FACU	Clarkson et al 2021
Onopordum acanthium	ONOACA	UPL	default UPL
Oplismenus hirtellus subsp. imbecillis	OPLHSI	FACU	Clarkson et al 2021
Osmunda regalis	OSMREG	OBL	Clarkson et al 2021
Oxalis corniculata	OXACOR	FACU	Clarkson et al 2021
Oxalis exilis	OXAEXI	FAC	Clarkson et al 2021
Paesia scaberula	PAESCA	FACU	Clarkson et al 2021
Paraserianthes lophantha	PARLOP	UPL	Clarkson et al 2021
Parsonsia capsularis	PARCAP	UPL	default UPL
Parsonsia heterophylla	PARHET	FACU	Clarkson et al 2021
Paspalum dilatatum	PASDIL	FACU	Clarkson et al 2021
Paspalum distichum	PASDIS	FACW	Clarkson et al 2021
Paspalum orbiculare	PASORB	FAC	Auckland Council
Paspalum urvillei	PASURV	FAC	Clarkson et al 2021
Paspalum vaginatum	PASVAG	FACW	Clarkson et al 2021
Pennantia corymbosa	PENCOR	FACU	Auckland Council
Pentapogon crinitus	PENCRI	UPL	default UPL
Persicaria decipiens	PERDEC	OBL	Clarkson et al 2021
Persicaria hydropiper	PERHYD	FACW	Clarkson et al 2021
Persicaria maculosa	PERMCL	FACW	Clarkson et al 2021
Persicaria perfoliata	PERPER	FAC	USDA
Persicaria punctata	PERPUN	FACW	Clarkson et al 2021
Phalaris arundinacea	PHAARU	FACW	Clarkson et al 2021

Taxa	NVSCode	WLStatus	WLStatusSource
Phormium tenax	PHOTEN	FACW	Clarkson et al 2021
Phyllocladus trichomanoides	PHYTRI	FACU	Clarkson et al 2021
Physalis peruviana	PHYPER	UPL	USDA
Phytolacca octandra	PHYOCT	FACU	Clarkson et al 2021
Pinus pinaster	PINPIN	FACU	Clarkson et al 2021
Pinus radiata	PINRAD	FACU	Clarkson et al 2021
Piper excelsum	PIPEXC	UPL	Clarkson et al 2021
Pittosporum crassifolium	PITCRF	UPL	default UPL
Pittosporum eugenioides	PITEUG	UPL	Clarkson et al 2021
Pittosporum tenuifolium	PITTEN	FACU	Clarkson et al 2021
Plagianthus divaricatus	PLADIV	FACW	Clarkson et al 2021
Plagianthus regius	PLAREG	FACU	Clarkson et al 2021
Plantago australis	PLAAUS	FAC	Clarkson et al 2021
Plantago coronopus	PLACOR	FAC	Clarkson et al 2021
Plantago lanceolata	PLALAN	FACU	Clarkson et al 2021
Plantago major	PLAMAJ	FACU	Clarkson et al 2021
Plectranthus ciliatus	PLECIL	FACU	Auckland Council
Pneumatopteris pennigera	PAKPEN	FACU	Clarkson et al 2021
Poa anceps	POAANC	FACU	Clarkson et al 2021
Poa trivialis	POATRI	FACU	Clarkson et al 2021
Podocarpus totara	PODTOT	FACU	Clarkson et al 2021
Polypogon monspeliensis	POLMON	FAC	Clarkson et al 2021
Polystichum neozelandicum	POLNEO	UPL	default UPL
Pomaderris amoena	POMAMO	UPL	default UPL
Populus deltoides	POPDEL	FACU	Clarkson et al 2021
Populus yunnanensis	POPYUN	UPL	default UPL
Potamogeton cheesemanii	POTCHE	OBL	Clarkson et al 2021
Potamogeton crispus	POTCRI	OBL	Clarkson et al 2021
Potentilla indica	POTIND	FACU	USDA
Potentilla reptans	POTREP	FAC	Clarkson et al 2021
Prunella vulgaris	PRUVUL	FACU	Clarkson et al 2021
Prunus campanulata	PRUCAM	UPL	default UPL
Pseudognaphalium luteoalbum	PSELUT	FACU	Clarkson et al 2021
Pseudopanax arboreus	PSEARB	UPL	Clarkson et al 2021
Pseudopanax crassifolius	PSECRA	FACU	Clarkson et al 2021
Pseudopanax crassifolius x lessonii	PSECXL	FACU	Auckland Council
Psoralea pinnata	PSOPIN	UPL	default UPL
Pteridium esculentum	PTEESC	FACU	Clarkson et al 2021
Pteris macilenta	PTEMAC	UPL	default UPL
Pteris saxatilis	PTESAX	UPL	default UPL
Pteris tremula	PTETRE	FACU	Clarkson et al 2021
Pterophylla sylvicola	PTESYL	FACU	Clarkson et al 2021
Pterostylis trullifolia	PTETRU	UPL	default UPL
Pyrrosia elaeagnifolia	PYRELE	UPL	Clarkson et al 2021
Ranunculus amphitrichus	RANAMP	OBL	Clarkson et al 2021
Ranunculus flammula	RANFLA	FACW	Clarkson et al 2021
Ranunculus macropus	RANMAC	OBL	Clarkson et al 2021
Ranunculus repens	RANREP	FAC	Clarkson et al 2021
Ranunculus sceleratus	RANSCE	OBL	Clarkson et al 2021
Rhamnus alaternus	RHAALA	FACU	USDA
Rhaphiolepis bibas	ERIJAP	UPL	default UPL
Rhopalostylis sapida	RHOSAP	FACU	Clarkson et al 2021
Ripogonum scandens	RIPSCA	FACU	Clarkson et al 2021
Rubus cissoides	RUBCIS	FACU	Clarkson et al 2021

Taxa	NVSCode	WLStatus	WLStatusSource
Rubus fruticosus	RUBFRU	FAC	Clarkson et al 2021
Rumex acetosella	RUMACE	FACU	Clarkson et al 2021
Rumex conglomeratus	RUMCON	FAC	Clarkson et al 2021
Rumex crispus	RUMCRI	FAC	Clarkson et al 2021
Rumex obtusifolius	RUMOBT	FAC	Clarkson et al 2021
Rumex pulcher	RUMPUL	FAC	USDA
Rumex sagittatus	RUMSAG	FACU	Clarkson et al 2021
Rumohra adiantiformis	RUMADI	UPL	Clarkson et al 2021
Sagina procumbens	SAGPRO	FACU	Clarkson et al 2021
Salicornia quinqueflora	SALQUI	FACW	Clarkson et al 2021
Salix alba	SALALB	FACW	Clarkson et al 2021
Salix babylonica	SALBAB	FACW	Clarkson et al 2021
Salix cinerea	SALCIN	FACW	Clarkson et al 2021
Salix xfragilis	SALXFR	FACW	Clarkson et al 2021
Samolus repens	SAMREP	FACW	Clarkson et al 2021
Schefflera digitata	SCHDIG	FACU	Clarkson et al 2021
Schoenoplectus pungens	SCHPUN	OBL	Clarkson et al 2021
Schoenoplectus tabernaemontani	SCHTAB	OBL	Clarkson et al 2021
Schoenus brevifolius	SCHBRE	FACW	Clarkson et al 2021
Schoenus maschalinus	SCHMAS	FACW	Clarkson et al 2021
Schoenus nitens	SCHNTE	FACW	Clarkson et al 2021
Schoenus tendo	SCHTEN	FAC	Clarkson et al 2021
Scrophularia auriculata	SCRAUR	FAC	Clarkson et al 2021
Selaginella kraussiana	SELKRA	FAC	Clarkson et al 2021
Senecio bipinnatisectus	SENBIP	FACU	Clarkson et al 2021
Senecio biserratus	SENBIS	UPL	default UPL
Senecio diaschides	SENDIA	UPL	default UPL
Senecio esleri	SENESL	UPL	default UPL
Senecio glomeratus	SENGLO	FACU	Clarkson et al 2021
Senecio hispidulus	SENHIS	UPL	Clarkson et al 2021
Senecio madagascariensis	SENMAD	UPL	Auckland Council
Senecio minimus	SENMIN	FACU	Clarkson et al 2021
Senecio skirrhodon	SENSKI	UPL	default UPL
Senecio vulgaris	SENVUL	FACU	USDA
Sigesbeckia orientalis	SIGORI	UPL	default UPL
Silybum marianum	SILMAR	UPL	default UPL
Sison amomum	SISAMO	UPL	default UPL
Sisymbrium officinale	SISOFF	UPL	default UPL
Solanum americanum	SOLAME	FACU	Clarkson et al 2021
Solanum chenopodioides	SOLCHE	FACU	Clarkson et al 2021
Solanum linnaeanum	SOLLIN	UPL	default UPL
Solanum marginatum	SOLMAR	UPL	default UPL
Solanum mauritianum	SOLMAU	UPL	Clarkson et al 2021
Solanum nigrum	SOLNIG	FACU	Clarkson et al 2021
Solanum opacum	SOLOPA	UPL	default UPL
Solanum villosum	SOLVIL	UPL	Clarkson et al 2021
Sonchus arvensis	SONARV	FACU	Clarkson et al 2021
Sonchus asper	SONASP	FACU	Clarkson et al 2021
Sonchus oleraceus	SONOLE	FACU	Clarkson et al 2021
Sparganium subglobosum	SPASUB	OBL	Clarkson et al 2021
Sporobolus africanus	SPOAFR	FACU	Clarkson et al 2021
Stachys sylvatica	STASYL	FACU	Bev Clarkson (pers comm)
Stellaria alsine	STEALS	FACW	Clarkson et al 2021
Stellaria gracilenta	STEGRA	UPL	default UPL

Taxa	NVSCode	WLStatus	WLStatusSource
Stellaria pallida	STEAPE	UPL	default UPL
Suaeda novae-zelandiae	SUANOV	FAC	Clarkson et al 2021
Symphyotrichum lanceolatum	SYMLAN	FACW	USDA
Symphyotrichum subulatum	SYMSUB	FAC	Clarkson et al 2021
Syzygium maire	SYZMAI	OBL	Clarkson et al 2021
Syzygium smithii	SYZSMI	UPL	default UPL
Taraxacum officinale	TAROFF	FACU	Clarkson et al 2021
Taxodium distichum	TAXDIS	OBL	Bev Clarkson (pers comm)
Tetragonia implexicoma	TETTRI	UPL	default UPL
Tetraria capillaris	NETCAP	FACW	Clarkson et al 2021
Thelypteris confluens	THECON	OBL	Clarkson et al 2021
Tmesipteris elongata	TMEELO	UPL	Clarkson et al 2021
Tmesipteris lanceolata	TMELAN	FACU	Auckland Council 2022
Tmesipteris tannensis	TMETAN	UPL	default UPL
Torilis arvensis	TORARV	UPL	default UPL
Trachycarpus fortunei	TRAFOR	FAC	Auckland Council
Tradescantia fluminensis	TRAFLU	FACU	Clarkson et al 2021
Trifolium arvense	TRIARV	UPL	Clarkson et al 2021
Trifolium pratense	TRIPRA	FACU	Clarkson et al 2021
Trifolium repens	TRIREP	FACU	Clarkson et al 2021
Triglochin striata	TRISTA	OBL	Clarkson et al 2021
Tropaeolum majus	TROMAJ	UPL	USDA
Typha orientalis	TYPORI	OBL	Clarkson et al 2021
Ulex europaeus	ULEEUR	FACU	Clarkson et al 2021
Utricularia gibba	UTRGIB	OBL	Clarkson et al 2021
Utricularia livida	UTRLIV	OBL	Bev Clarkson (pers comm)
Verbena bonariensis	VERBON	FACU	Clarkson et al 2021
Verbena incompta	VERINC	FACU	USDA
Veronica macrocarpa	VERMAC	UPL	default UPL
Veronica persica	VERPER	UPL	default UPL
Veronica serpyllifolia	VERSER	FAC	Clarkson et al 2021
Veronica stricta	VERSTR	FACU	Clarkson et al 2021
Vinca major	VINMAJ	FACU	USDA
Viola arvensis	VIOARV	UPL	default UPL
Vitex lucens	VITLUC	UPL	Clarkson et al 2021
Vitis vinifera	VITVIN	UPL	default UPL
Vulpia bromoides	VULBRO	UPL	USDA
Watsonia meriana	WATMER	FAC	Auckland Council
Wolffia australiana	WOLAUS	OBL	Clarkson et al 2021
Zantedeschia aethiopica	ZANAET	FAC	Clarkson et al 2021
Zizania latifolia	ZIZLAT	OBL	Clarkson et al 2021

6.2 Appendix 2. Pest plant species

Pest plant taxa	NVSCode	Pest plant taxa	NVSCode
Acacia longifolia	ACALON	Iris pseudacorus	IRIPSE
Acacia mearnsii	ACAMEA	Jacobaea vulgaris	JACVUL
Acaena agnipila	ACAAGN	Juncus acutus	JUNACS
Ageratina adenophora	AGEADE	Juncus articulatus	JUNART
Ageratina riparia	AGERIP	Juncus bulbosus	JUNBUL
Agrostis capillaris	AGRCAP	Leucanthemum vulgare	LEUVUL
Alisma plantago-aquatica	ALIPLA	Leycesteria formosa	LEYFOR
Allium triquetrum	ALLTRI	Ligustrum lucidum	LIGLUC
Alnus glutinosa	ALNGLU	Ligustrum sinense	LIGSIN
Alocasia brisbanensis	ALOBRI	Lolium perenne	LOLPER
Alternanthera philoxeroides	ALTPHI	Lonicera japonica	LONJAP
Araujia sericifera	ARASER	Ludwigia peploides	LUDPEP
Archontophoenix cunninghamiana	ARCCUN	Lycopus europaeus	LYCEUR
Aristea ecklonii	ARIECK	Medicago lupulina	MEDLUP
Artemisia verlotiorum	ARTVER	Myriophyllum aquaticum	MYRAQU
Asparagus asparagoides	ASPASP	Osmunda regalis	OSMREG
Asparagus scandens	ASPSCA	Paraserianthes lophantha	PARLOP
Azolla pinnata	AZOPIN	Paspalum distichum	PASDIS
Berberis glaucocarpa	BERGLA	Paspalum vaginatum	PASVAG
Bidens frondosa	BIDFRO	Persicaria perfoliata	PERPER
Calystegia silvatica	CALSIL	Phalaris arundinacea	PHAARU
Carex divisa	CARDVS	Pinus pinaster	PINPIN
Carex divulsa	CARDIV	Pinus radiata	PINRAD
Carex leporina	CARLEP	Plectranthus ciliatus	PLECIL
Carex scoparia	CARSCO	Potamogeton crispus	POTCRI
Cenchrus clandestinus	CENCLA	Prunus campanulata	PRUCAM
Cenchrus purpurascens	CENPUP	Psoralea pinnata	PSOPIN
Ceratophyllum demersum	CERDEM	Rhamnus alaternus	RHAALA
Cestrum nocturnum	CESNOC	Rhaphiolepis bibas	ERIJAP
Cirsium arvense	CIRARV	Rubus fruticosus	RUBFRU
Cirsium vulgare	CIRVUL	Rumex sagittatus	RUMSAG
Cortaderia jubata	CORJUB	Sagina procumbens	SAGPRO
Cortaderia selloana	CORSEL	Salix cinerea	SALCIN
Crataegus monogyna	CRAMON	Salix xfragilis	SALXFR
Crocosmia xcrocosmiiflora	CROXCR	Selaginella kraussiana	SELKRA
Cynodon dactylon	CYNDAC	Senecio skirrhodon	SENSKI
Cyperus eragrostis	CYPERA	Silybum marianum	SILMAR
Dactylis glomerata	DACGLO	Solanum linnaeanum	SOLLIN
Delairea odorata	DELODO	Solanum marginatum	SOLMAR
Digitalis purpurea	DIGPUR	Solanum mauritianum	SOLMAU
Ehrharta erecta	EHRERE	Syzygium smithii	SYZSMI
Erica lusitanica	ERILUS	Trachycarpus fortunei	TRAFOR
Erythrina xsykesii	ERYXSY	Tradescantia fluminensis	TRAFLU
Glyceria declinata	GLYDEC	Tropaeolum majus	TROMAJ
Glyceria maxima	GLYMAX	Ulex europaeus	ULEEUR
Hedera helix	HEDHEL	Utricularia gibba	UTRGIB
Hedychium gardnerianum	HEDGAR	Utricularia livida	UTRLIV
Helosciadium nodiflorum	HELNOD	Vinca major	VINMAJ
Hesperocyparis macrocarpa	HESMAC	Vitis vinifera	VITVIN
Holcus lanatus	HOLLAN	Watsonia meriana	WATMER
Homalanthus populifolius	HOMPOP	Zantedeschia aethiopica	ZANAET
Hypericum androsaemum	HYPAND	Zizania latifolia	ZIZLAT
Ipomoea indica	IPOIND		

6.3 Appendix 3. Threatened, at-risk and data deficient species in rotation 3 (2020-2024)

Species	National Threat Classification	Regional Threat Classification
Agathis australis	At Risk	At Risk
Alternanthera denticulata		Threatened
Azolla rubra		At Risk
Cardamine forsteri		At Risk
Carex fascicularis	At Risk	At Risk
Carex ochrosaccus		At Risk
Carex subdola		Threatened
Coprosma repens		At Risk
Coprosma tenuicaulis		At Risk
Cyclosorus interruptus	At Risk	Threatened
Dianella haematica		At Risk
Eleocharis gracilis		At Risk
Empodisma robustum	At Risk	At Risk
Epilobium chionanthum	At Risk	Threatened
Epilobium pallidiflorum		At Risk
Fuchsia excorticata		At Risk
Galium propinquum		At Risk
Gleichenia microphylla		At Risk
Hydrocotyle pterocarpa		At Risk
Isolepis distigmatosa		Threatened
Isolepis inundata		Threatened
Juncus pauciflorus	Threatened	Threatened
Juncus prismatocarpus		Threatened
Kunzea robusta		At Risk
Lemna disperma		Data Deficient
Lemna minor		Data Deficient
Machaerina arthrophylla		At Risk
Machaerina tenax		At Risk
Metrosideros diffusa		At Risk
Metrosideros excelsa		At Risk
Nertera scapanioides		At Risk
Olearia solandri	At Risk	At Risk
Paspalum orbiculare	Threatened	Threatened
Pennantia corymbosa		Threatened
Pittosporum eugenioides		Data Deficient
Ranunculus amphitrichus		Threatened
Ranunculus macropus	At Risk	Threatened
Schoenus nitens		Threatened
Senecio diaschides		At Risk
Senecio minimus		At Risk
Sparganium subglobosum		Threatened
Syzygium maire	Threatened	Threatened
Thelypteris confluens	At Risk	Threatened

Find out more:
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