Monitoring natural wetlands in Otago under the requirements of the National Policy Statement for Freshwater Management (2020)

Otago Regional Council

Lake Tuakitoto Wetlands / Roto-nui-a-Whatu, Kaitangata, Otago

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Summary

This report sets out a framework and methods for monitoring wetlands in Otago as part of the implementation of the National Policy Statement for Freshwater Management 2020 (NPS-FM 2020; Ministry for the Environment, 2020). The core objectives of the NPS-FM are to ensure the health and well-being of water bodies and freshwater ecosystems; the health needs of people; and provision for social, economic, and cultural well-being. A key policy (13) is the systematic monitoring of the condition of wetlands over time, using methods that allow policies to be implemented that reverse any deteriorating trends. We deconstruct the requirements of the NPS for monitoring, develop an operational definition of wetland health and condition, consider the major Otago Regional Council policies related to wetlands, and detail metrics and approaches for assessing wetland condition. We offer these monitoring suggestions for discussion and recognise that in some areas other expertise is required (e.g., cultural values, fish, birds, phytoplankton, hydrology etc). However, irrespective of the methodology adopted, we advocate that NPS-FM objectives, ORC policies/regulations, and wetland condition and extent metrics are clearly linked to facilitate a common understanding of monitoring rationale, and to focus attention on where improvements may be needed in the future. The Otago region supports the most diverse and numerous wetland types of any region in New Zealand, and monitoring condition and extent will require a suite of methods at different scales to adequately report on progress towards maintaining and enhancing their health.

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1. Introduction

Wetland monitoring is a foundational component of the NPS FM (2020) to ensure policies and regulations by Regional Councils maintain and enhance wetland condition and extent. We note that the NPS FM was revised in 2022 and not finalised in its current form until 2023. However, throughout this report we reference the original date (2020) for continuity and convenience.

In summary the NPS FM (2020) requires that sites selected for monitoring need to be:

- Representative of the natural wetland types within Freshwater Management Units (FMU);
- Include all outstanding water bodies and culturally significant sites;
- Include primary contact sites having significant human use for recreational and other purposes;
- Sufficient in number to show reliable trends for extent and condition of wetlands in the Freshwater Management Unit (FMU).

These parameters prescribe the selection of wetlands which we have discussed previously (Lee and Johnson 2023), in a report for the Otago Regional Council (ORC). The Otago context is unusual nationally because the range and number of wetlands in the region is the greatest in New Zealand. In this report we explore monitoring methods for wetlands to assist the ORC to meet national monitoring policies.

1.1 Wetland Condition Index

Wetlands have long been recognised in New Zealand as one of the most threatened ecosystems nationally, with over 90% having been lost, mainly through drainage and subsequent pasture and urban development. Many remaining wetlands have been further severely modified by fire, stock grazing, invasive pests and weeds, and encroaching intensive landuse. Recognition of the multiple values of wetlands, particularly those in largely agricultural landscapes, emerged during the latter part of the 20th Century, and resulted in several initiatives to protect and restore the relatively few wetlands remaining. At a policy level, these actions have been co-ordinated by the Ministry for the Environment.

To highlight the biodiversity values of wetlands, Johnson and Gerbeaux (2004) identified the range of wetland types in New Zealand and around the same time Clarkson et al. (2003) developed an assessment methodology for measuring the condition of wetlands; the Wetlands Condition Index (WCI), which has been adopted, with some modifications, by many Regional Councils and the

Ministry for the Environment. The Clarkson et al. (2003) approach assessed hydrological integrity; physico-chemical parameters; ecosystem intactness; browsing; predation and harvesting regimes; and the dominance of native plants. The aim was to provide semi-quantitative measures for assessing change against estimated baselines. Councils have used this approach, and a few have undertaken repeat measures. The standardised methodology was initially developed for reporting under international agreements such as the UN Convention on Biological Diversity and the Ramsar Convention on Wetlands. Our understanding is that the Ministry of Environment is currently progressing developments of the WCI to specifically fit the requirements of the NPS FM (2020).

We shall discuss the Wetland Condition Index further later in the report, but it was explicitly developed to recognise both the values and the threats associated with wetlands, to improve their health and viability across the landscape. Bellingham et al. (2021) also recommend the WCI for wetlands in a report outlining standardised methods for Regional Councils monitoring ecological integrity. They suggest permanent plot-based sampling across all vegetation types, along with five-minute bird counts and chewcards for assessing possum abundance. Bellingham et al. (2021) link the sampling to reporting on ecological integrity, following the Department of Conservation's biodiversity assessment framework (McGlone et al. 2020).

1.2 Current method developments

We are aware that the Ministry for the Environment is also working on a standardised methodology for assessing wetlands. A scoping report by Collins Consulting (2022) has examined the application of National Environmental Monitoring Standards (NEMS) for wetland monitoring. The NEMS programme proposes standardised methodology for consistent and robust environmental monitoring and reporting across regional and central government agencies. Such standardisation will be essential for reporting progress at a national scale towards the central objectives of the NPS FM (2020).

The Collins (2022) report summarises the findings of two workshops and identifies mapping and technical issues that require further development before regional government can deliver on the monitoring required for the NPS FM (2020). Specifically, Collins (2022) notes that mapping of wetland extent, designating wetland type, identifying and detecting threatened species, and mapping of ephemeral and forested wetlands remain unresolved issues. Based on implementing monitoring in the short-term, Collins (2022) indicates the current absence of suitable methods for the following attributes, in decreasing order of priority: 1. Water quality monitoring; 2. Native bird monitoring; 3. Water quantity monitoring; 4. Mātauranga Māori; 5. Monitoring plant species; 6. Fish monitoring; 7. Hydrological impacts of activities; 8. Phytoplankton; 9. Aquatic invertebrate monitoring; 10. Terrestrial invertebrate monitoring; 11. Community representation and composition.

We acknowledge that many components of wetland ecosystem function, and biodiversity in general, currently lack precise detection and monitoring tools. However, we believe the necessary tools are available to adequately assess condition trends, based on a nested and hierarchical view of biodiversity whereby recognition of composition and structure at one level sustains persistence at lower levels in the ecosystem. Although new methods will help inform and possibly improve a WCI, in our view there are currently sufficient techniques and information available to have confidence in a WCI for assessing and reporting on wetland condition and extent.

As the Collins (2022) report acknowledges, Mātauranga Māori of wetlands reflects the special knowledge and values of Māori, and identification and discussion of these is the perogative of Te Rūnanga o Ngāi Tahu.

To develop suitable methods for the NPS FM (2020), the Collins report (2022) envisages NEMS getting funding to assist regional councils and government agencies in developing standardised methodologies for wetland monitoring, based on additional workshops to develop a minimum set of wetland variables and indicators to be monitored. We are not aware of the timeline for these workshops or of progress to date.

In its assessment of current council activities, the Collins report (2022) notes that few if any councils have remapped wetland extent to measure changes, and that half the councils have applied the Wetland Condition Index (Clarkson et al. 2003), but some believe it is too subjective to be used reliably, particularly when different observers are used to assess change over time.

Overall, our feedback from councils indicates that the current WCI is generally adequate for assessing wetland condition or state but perhaps less suitable for monitoring trends over time, mostly due to the qualitative character of assessments for many parameters. Judgments about wetland features also contrast with other aspects of the NPS FM (2020) that are clearly quantitatively defined such as the Attributes Requiring Limits on Resource Use, and the Attributes Requiring Action Plans, the latter including several biodiversity elements (e.g. Macroinvertebrates, Fish, Submerged plants).

1.3 Baselines

The NPS FM (2020) requires that ecological condition be assessed in relation to baseline or reference states, especially when progress is being assessed or changes interpreted. McGlone et al. (2020) argue that prehuman baselines have an "important but subsidiary role in countering a reduced sense of possibilities" informing ecosystem condition and restoration. The idea of an historic template may be useful when types of wetlands dominated by range-restricted endemic species are being considered. One example is the *Sporadanthus ferrugineus* lowland restiad peat bogs in the Waikato that require a combination of peat, water-table levels, and nutrients to persist. Here, historic information could inform restoration planting of suitable compatible species to sustain the bog community. Historic templates could be particularly useful when seeking to restore woody components to many wetlands where fire, both natural and human, has eliminated tree and shrub species from these areas. Historic information could help guide the selection of target species to restore structural complexity and improve habitat diversity for associated animals.

Often baselines are developed by comparing focal sites with less modified or unmodified sites, in similar environments, termed reference sites. However, most types of baseline are difficult because of the lack of direct historic analogues of what is occurring in the current wetland environment after over 800 years of human settlement in New Zealand, compounded by post-industrial climate changes.

At a conservation level, the cost of micro-managing specific compositional and/or structural assemblages in wetlands, to reflect a notional historic assemblage, is, in our view, both unsustainable and unachievable. Moreover, fossilising notional past or current habitat expressions in the 21st century will only increase their vulnerability when management and the climate invariably changes.

In our view enhancing "current status" is a more relevant paradigm for assessing wetland change, while the trajectory can be assessed using criteria developed for "enhanced condition". This would focus on sustaining hydrological regimes, the dominance of indigenous biota, and maintaining representative wetland types, threatened species, and wetland extant, without having to use reference sites to calibrate any condition index.

1.4 Ecological Health and Ecological Integrity

Ecosystem Health and Ecological Integrity are widely used in environmental assessment planning and measurement but need to be clearly defined to be useful operationally. Both have been applied in the New Zealand context by McGlone et al. (2020). They view Ecosystem Health (EH) as a high-level environmental goal attained when an ecosystem has achieved its inherent potential, is stable, resilient, and self-managing, supporting a full range of ecosystem services. However, many of these criteria are challenging to define and achieve, and perhaps inappropriate, to apply to wetlands that are inherently transient in time and space over millennia and dependent on adequate hydrological regimes.

McGlone et al. (2020) outline the history of the use of Ecological Integrity and its close association with identifying "natural" ecosystems. They note that in New Zealand, the definition of Ecological Integrity in the New Zealand Environmental Reporting Act 2015: is "..the full potential of indigenous biotic and abiotic features and natural processes, functioning in sustainable communities, habitats, and landscapes", which was adopted from Lee et al. (2005), who went on to say that: "…at larger scales, ecological integrity is achieved when ecosystems occupy their full environmental range." As McGlone et al. (2020) note, Ecological Health refers to ecosystem function generally while Ecological Integrity relates to the specific character, especially the indigenous biotic components.

McGlone et al. (2020) list eight biodiversity outcomes for the National Biodiversity Assessment Framework currently being used by the Department of Conservation. Although we are considering wetland monitoring in the context of the NPS FM 2020, measurements obtained from these habitats may be useful to inform broader biodiversity and environmental requirements.

The Department of Conservation biodiversity outcomes, listed by McGlone et al (2020), are as follows:

1. ***Maintaining ecosystem processes:*** The extent to which the environment can support indigenous ecosystems and the degree to which they are free of disturbance factors that lead to poor ecological outcomes.
2. ***Limiting environmental contaminants:*** Presence and concentration in the environment of non-nutrient contaminants including faecal bacteria from mammalian sources, vertebrate toxins, pesticide residues and heavy metals, hormones or hormone mimics as a result of human activities. Persistent litter and disruptive noise in the aquatic environment.

3. ***Reducing spread and dominance of exotic species:*** Documentation of the presence, dominance, and rate of increase of exotic species in the natural environment.
4. ***Preventing declines and extinctions:*** Conservation status of all species in the New Zealand biota (per the New Zealand Threat Classification System); security of threatened and at-risk taxa; loss of genetic diversity in critically reduced taxa.
5. ***Maintaining ecosystem composition:*** Demography of functional groups, their representation, abundance of common and widespread taxa and changes in species diversity.
6. ***Ensuring ecosystem representation:*** The extent, protection status and ecological condition of indigenous ecosystems.
7. ***Adapting to climate change:*** Documentation of changing climates, and the biological responses.
8. ***Human use and interaction with natural heritage:*** Documentation of how humans interact with natural ecosystems in their harvesting of both indigenous and exotic taxa, through recreating in them, and how they use them to gain spiritual and physical wellbeing.

These intended biodiversity outcomes comprise stressors (e.g. exotic species dominance, environmental contaminants, human use) and features or attributes (e.g. ecosystem process, representativeness, and composition), in addition to providing resilience to climate change. Ideally, any wetland condition monitoring should provide metrics including many of these potential positive biodiversity outcomes. Traditionally, environmental monitoring and reporting have adopted a Drivers/State framework, which loosely corresponds to Stressor/Attribute. However, these frameworks need to be flexible enough to capture new drivers or stressors of ecosystem change that emerge and not presume the relative importance of interactions that may be historical.

2. Wetland Monitoring Systems

We have not undertaken a global review of the literature, based on the view that New Zealand developments in biodiversity assessment are relatively advanced. Dorney et al. (2018) provide a useful overview of rapid wetland assessments and condition indices, mostly from the USA and Canada, countries where wetland monitoring is mandated by legislation. They focus on standardised procedures to rate the ecological status and/or ecosystem services or resilience of a wetland site which are generally assessed against a reference site. Amongst the issues highlighted are site versus context definitions, biodiversity condition index measurements, identification of key function components, and the inclusion of human use metrics. Verification and validation of the metrics used are also issues in many jurisdictions, particularly when legal challenges occur. In their compilation, Clarkson and Sorrell (2018) provide a case study using an iteration of the New Zealand Wetland Condition Index (WCI) which we discuss later.

Our overall impression from the international experience and literature is that many countries still struggle to have clear definitions of wetland types, and of the development of quantitative and relevant metrics for wetland condition. Often these issues reflect the scale and diversity of wetland types present, the complex habitat drivers and threshold states, the dynamic character of these habitats, and the measurement and comparison of non-fungible values. Many studies focus on validation and/or calibration of metrics for wetland condition, attempting to demonstrate that they reliably measure the purported function or process or values (Dorney et al. 2018). Often the methods need to withstand judicial scrutiny.

In New Zealand, in contrast, we already have a clear understanding of the different wetland types which have been determined independently from assessments of wetland condition. In other countries, typology and condition are often assessed simultaneously using the same or similar methodology. As a multi-island continent, New Zealand wetlands are generally smaller and more clearly circumscribed, compared to those in North America where most monitoring has been undertaken. In other countries, reference sites or baselines are also advocated for assessing wetland condition or providing guidelines for restoration. As indicated previously, we suggest these be used with caution, given past modifications, current environmental and climate changes, and the novel context of many wetlands in lowland and montane zones where diverse land uses now exist. Most of the rapid assessments developed for wetlands overseas have several components that measure landscape stressors, buffer features and wetland site conditions. These measures help explain condition trends in the associated wetlands. We support this framework for New Zealand as wetland conditions are strongly influenced by both adjoining and catchment land use. Over decades, the types and scale of land use nearby and in the catchment generally will inform understanding of monitoring trends in wetland condition. They will assist with defining the stressors impacting on wetlands and help with developing relevant policies to foster wetland enhancement.

3. Functional equivalence

One issues that arises when developing a WCI is the relative value of exotic or introduced species in wetland ecosystems today, when many indigenous taxa are now extinct or rare or threatened. We have argued that many introduced birds associated with wetlands are fulfilling roles previously occupied by extinct bird species, and therefore should be retained. However, we respect the role of Fish and Game to maintain these species at population levels compatible with other landuses in the wetland catchment.

Trout have a special place in New Zealand hunting culture, mostly in larger water courses (streams/rivers) that dissect wetlands, but also occur elsewhere. They are major predators of native fish and there are current plans to limit the migration of trout in parts of remote river systems. This will also benefit many wetland ecosystems.

Perhaps a greater challenge are the introduced plants that are difficult to detect and control. Most naturalised woody taxa are functionally distinct from comparable indigenous species and can be eliminated from wetlands. However, many (not all) introduced herbaceous sedges and grasses likely have functions similar to indigenous growth forms and are not a priority for control.

We accept that discriminating between disparate and equivalent functional types across indigenous and introduced groups of biota is not easy, and will depend on regional and local abundance of the exotic species and the practically of removal without fostering consolidation and spread of the naturalised species.

4. Policy Context - ORC Land and Water Regional Plan

The NPS FM 2020 requires that monitoring in wetlands both informs policy and can be used to evaluate effectiveness of different regulations, such that monitoring will be applied to refine existing or new policies.

The ORC has already developed requirements for wetlands in their draft Land and Water Regional Plan (dLWRP) (summarised in Appendix 1 – provided by Dr Sami Khan). The objectives of the dLWRP capture the major intention of the NPS FM 2020, namely, to maintain or enhance wetland values, especially those considered already as being regionally significant. However, the NPS FM 2020 intentionally encompasses all natural wetlands across Otago, in recognition of their depletion nationally.

The policies in the dLWRP specifically identify threatened species, habitat for wetland dependent biota, diversity of habitat types, naturalness, uncommon habitats, culturally significant sites, diversity of biota, waterfowl habitat, and hydrological values. The policies also seek to promote the conservation, creation and reinstatement of wetland areas, and enhancement of individual and collective wetland values through education, fencing out livestock, research and monitoring, restoration, community engagement, and partnerships. Some of these policies, such as the creation of new wetlands, education and research are beyond the requirements of the NPS FM 2020. The potential threats to wetlands from commercial harvesting, certain types of restoration activity and research, and modification, directly and indirectly through drainage overlap with the NPS FM 2020 intentions.

Overall, the ORC dLWRP policies are supportive of achieving the aims of the NPS FM 2020, and any monitoring established should be able to assist the ORC in reporting on these. However, many of the attributes identified in the draft plan will require further definition to be amenable for inclusion in any condition index (e.g. naturalness, habitat diversity, hydrological values, etc).

5. Useful spatial databases

There is a growing number of national spatial databases on landuse, environment and climate that are regularly updated, and therefore can be used to measure temporal changes in climate and agricultural activity at the regional and FMU scale. The main providers (StatsNZ, Asurequality, NIWA, Manaaki Whenua – Landcare Research) are developing new layers from the primary data collected to assist a range of groups and agencies with environmental assessment and reporting. These can also be used to determine regional and catchment stressors on wetland habitats. We discuss several of these below but are aware that these agencies are developing new products for GIS use and environmental analyses.

5.1 AgriBase

AgriBase is a national database on farm location and landuse, available from AsureQuality. It contains details about farm type, size, animal numbers by stock class, planted areas for different orchard or crop types (including forestry), and the spatial coordinates of the farm. The primary data at the farm level can be integrated with other metrics to investigate erosion, nutrient runoff and other potential spillover effects.

Recently, AsureQuality apparently withdrew support for AgriBase which had over time used different algorithms to provide a complete coverage. Stats NZ have developed the Agricultural

Production Survey which may be used to measure landuse intensification in catchments, depending on spatial accuracy and coverage.

5.2 Land Cover Database

The New Zealand Land Cover Database (LCDB) is a thematic classification of New Zealand's land cover and includes 33 mainland land cover classes. Commenced in 1995/96 (V1.), versions since V3. (2008/09) have some degree of back compatibility that facilitates assessment of landuse changes and trends over time. To date, LCDB has been used for national and regional environment monitoring, forest and shrubland inventory, biodiversity assessment, trend analysis, and infrastructure planning. The polygon-based mapping identifies wetlands, and the reliability of these will undoubtedly improve with time, especially as regional councils input their data into future iterations of LCDB. Dymond et al. (2021) combined LCDB information with that gathered as part of the Wetlands of National Importance (WONI) project in the 1990s to identify significant wetlands across New Zealand, although compiling this information at the scale required by the NPSFM (2020) will require extra effort and information sharing.

The cover classes recognised in LCDB include indigenous vegetation types (e.g. Tussock Grassland, Flaxland, Manuka & Kanuka, Broadleaved Indigenous Forest, Grey Scrub, Indigenous Forest), various agricultural/horticultural land use types (e.g. Cropland, Orchard and Vineyard, High Producing Grass), selected invasive plant pests (e.g. Gorse and Broom), forestry (e.g. Forest Harvested, Deciduous Hardwood, Exotic Forestry), and areas heavily modified for human use (e.g. Built up, Mines & Dumps). All of these have relevance for assessing wetland condition and associated threats to these habitats through water capture, nutrient runoff, sources of invasive species, and modification to streams and rivers sustaining the adjoining wetlands. They can be aggregated in different ways to identify potentially positive (e.g. proportion of catchment under indigenous cover) and negative (e.g. proportion of catchment under intensive agriculture; proportion of catchment under invasive weed species) to investigate potential drivers of wetland change at the FMU scale and larger. The utility of LCDB will depend on regular updated versions in a timeframe that supports the reporting requirements of the NPS FM (2020).

5.3 CliFlo

CliFlo is a publicly available NIWA database of climate station information collected on a regular basis from 600 meteorological stations scattered around New Zealand. Registration is required for access, but the data can be used to investigate trends in temperature and rainfall, seasonal and annual, that can inform any condition trends detected in wetlands across the Otago region and in different elevation bands. Recently NIWA have also developed a spatial New Zealand Drought Index based on a combination of Standardised Precipitation Index (SPI), Soil Moisture Deficit (SMD), Soil Moisture Deficit Anomaly (SMDA), and Potential Evapotranspiration Deficit (PED). They intend to update and make these available for each Territorial Local Authority on a regular basis via the web. The NZ Drought Index provides some of the information used in the official declaration of droughts but would provide information for assessing moisture stressors at the FMU level, either as continuous assessments or timeframe comparisons over successive monitoring periods. For example, increased or prolonged droughts anywhere in Otago will create local stress on wetlands, limiting water availability and threatening main hydrological drivers, especially in smaller catchments and at higher elevations. Although precipitation patterns cannot be controlled, ORC policies and regulations can limit water offtake through extraction consents and facilitate landuses with lower water demands.

6. Climate change mitigation

Current climate change predictions for Otago indicate significant shifts in hydrological regimes across the region that will impact wetlands, and adjustments in these ecosystems may provide early evidence of changes in temperature and precipitation. Such adjustments are most likely to be seen in catchments sourced and located in eastern regions where annual temperatures will increase and rainfall decrease, albeit with increasing storm events. Western wetlands are expected to experience similar or enhanced rainfall, and river sources along the main divide will continue to maintain current water flows with perhaps increased flooding events affecting associated wetlands. There may also be an expansion of local wetlands where current flood protection proves inadequate or too expensive to maintain. Expanding dry zones across eastern Otago will impact wetlands from lowland to alpine regions, perhaps causing shrinkage of wetlands dependent on local catchment runoff. These losses reflect natural turnover in wetlands and cannot be mitigated.

Sea level rises will see both increases and decreases in estuarine and coastal wetlands, depending on coastal topography. Apart from slowing maritime egress in certain areas, little can be done to halt impacts on wetlands in the medium term.

As this brief overview suggests, systemic climate change impacts on wetlands will cause both increases and decreases in wetland extent. Losses will likely be most pronounced in parts of the region experiencing drier ambient conditions. The montane, subalpine, and alpine peat bogs may be at greatest risk from drier conditions. However, gains will also occur where enhanced surface water creates new environments for wetlands, commonly in lowland environments.

In our view, the appropriate climate change mitigation strategy for wetlands is to reduce the local stressors and thereby enhance the condition of wetlands across Otago. Over evolutionary and ecological timescales, these habitats have always been spatially discrete, relatively small, and scattered across the landscape. Their biota is generally mobile and resilient at low population densities and therefore adapted to tracking wetland habitat whenever it is present. Since human settlement the loss of bird species and extensive forest habitat from interfluves, has significantly reduced major indigenous wetland elements, which will limit recovery options for wetlands generally. However, protecting extant hydrological regimes, eliminating ecosystem-modifying invasive plants and animals, and reducing the risk of major disturbances such as fire, will provide the best conditions for wetland viability and resilience, irrespective of local climate conditions. In other words, fulfilling the main intention of the NPS FM (2020) is the best strategy for sustaining representative wetland types and habitats for indigenous biota, ecosystem services and human activities.

7. Baselines and Reference wetlands

A comparative baseline from which natural disturbance responses and/or successional trajectories can be measured is in our view problematic, although required under the NPS FM (2020). As discussed previously, using a benchmark wetland to measure change in condition across all wetland types in each Freshwater Management Unit in Otago, would be both challenging and potentially misleading as the approach ignores near universal modifications to wetlands from fire, stock grazing, drainage, invasive species, and nutrient additions. Importantly, species extinctions and regional depletions of wetland species are in most instances irreversible. Moreover, most wetlands are transient, dynamic, complex, and responsive to a range of changing environmental conditions. This makes using a base-line typology challenging and potentially unhelpful.

Our ambitions for natural ecosystems such as wetlands should have broader goals that recognise their often-unknown past and acknowledge their uncertain future under rapid environmental change in an anthropogenically modified landscape. The key issue is how we define the condition or ecological integrity of wetlands to provide a basis for assessing any change.

We suggest that ORC use the definition of Ecological Integrity in the New Zealand Environmental Reporting Act 2015, given this definition is already operational in New Zealand legislation. Ecological Integrity is defined as "the full potential of indigenous biotic and abiotic features and natural processes, functioning in sustainable communities, habitats, and landscapes". Under this definition, wetland condition with high ecological integrity would include at least the following elements:

- Continuation of hydrological processes sustaining a wetland.
- Dominance of indigenous biota.
- Maintenance of plants and animal groups representative of the wetland type.
- Contribution of viable populations of threatened species, if present.
- Occurrence of different wetland types across FMUs.

These criteria recognise wetlands as dynamic habitats that are responding to historical and current environmental and biotic changes. The criteria are based on the premise that goals for wetland condition under the NPS FM (2020) centre on maintaining a full range of wetland types, all dominated by indigenous species representative of the habitat, including any threatened species present, and highlight the importance of sustaining the hydrological regime. In addition, the NPS FM (2020) identifies critical direct and indirect threats to wetlands that should be reduced. Any assessment of wetland condition needs to include attributes of the wetland, the buffer area adjoining the wetland, and the broader catchment context which impacts on the wetlands.

8. Monitoring challenges

The ambition is to have a wetland monitoring system that is fit for purpose, reliable, sustainable over the long-term, and effective and efficient for achieving the defined ecosystem goals, in this case, maintaining and enhancing the condition and extent of wetland ecosystems representative of the wetland types across the Otago region. Wright et al. (2020) outline DoC's recent experience in developing a national biodiversity assessment monitoring programme, which took six years to become operational. They emphasise the importance of collecting data relevant for management objectives and maintaining an adequate monitoring budget within the organisation, as key elements for sustaining the monitoring programme.

The NPS FM (2020) dictates the objectives for monitoring, but implementation requires deconstructing higher-level goals (e.g. condition and extent) into biodiversity and ecosystem condition features. In our view the metrics need to directly link to policy, and be parsimonious rather than comprehensive, because there are potentially a very large number of variables that could be measured. Other variables can be added as new issues emerge, but initially monitoring should, in our view, focus on core variables addressing the NPS FM priorities, as set out above. We also encourage dialogue with end-user groups about the rationale and reporting metrics used, in part to facilitate familiarity and acceptance of reporting trends.

Budget allocations for wetland reporting are beyond the scope of this report but will be a critical factor in sustaining the monitoring cycle. Some of the metrics will be GIS-based analyses of publicly available datasets and can be analysed inhouse cost-effectively. The increasing utility of remote sensing for measuring biodiversity change will also reduce costs.

9. Methods with potential to contribute towards a wetland condition index

New techniques will undoubtably emerge to assist environmental monitoring, especially for cryptic taxa, and below we discuss several likely candidates. The Macro-Invertebrate Community Index and eDNA (discussed further below) could be incorporated in measuring wetland condition through appropriate placement of monitoring sites that are regularly sampled. They are complementary and independent measures of biodiversity and can be used comparatively to test the relative accuracy of each index. Importantly they both measure very small components of biodiversity that generally comprise most of the species in any ecosystem, especially invertebrates.

A useful approach initially would be to include wetland and adjoining non-wetland areas, above and below the wetland site, across a range of wetland types and elevations, to understand the sensitivity and consistency of these biotic indices before they are used more widely to inform ecosystem condition assessments for the NPS FM (2020). The online Bird Atlas is also an innovation, providing a current assessment of bird ranges in New Zealand.

10. Macro-invertebrate Community Index

Many Regional Councils are currently using the Macro-Invertebrate Community Index (MCI) for assessing the health of aquatic ecosystems. Formalised and standardised by Stark et al. (2001), the MCI is developed for wadeable streams, and the protocols adopted vary depending on substrate (hard or soft) and the level of taxonomic expertise available. This biomonitoring approach was further operationalised by the Ministry for the Environment (Stark and Maxted 2007) to provide a standardised approach for Regional Councils and others to use for State of the Environment Reporting nationally. This report suggests several alternative indices, based on modifications to the MCI. The new indices use different taxonomic levels of invertebrate identification, and the inclusion of abundance values, and their accuracy varies depending on substrate and sampling effort/cost. Clapcott et al. (2017) examined predictors of stream MCI at national and regional (i.e. Auckland-Waikato and Wellington) scales using both linear and non-linear models. They used landcover and landuse stressors, environmental variables, and factors associated with geology and topography. At a national scale, the proportion of native vegetation in upstream catchments was the best predictor of MCI scores, while secondary predictors varied regionally.

11. eDNA

Environmental DNA (eDNA) metabarcoding is emerging as a potentially useful tool for measuring biodiversity in waterways based on residual DNA from organisms in the environment. Wilkinson et al. (2024) in a New Zealand study used the Taxon-Independent Community Index (TICI) approach based on the recognition of indicator species or groups using eDNA from water samples. They highlighted the advantages eDNA technology has over more traditional fauna and flora survey approaches, including greater detection sensitivity, ability to distinguish cryptic and new species and/or groups (e.g. bacteria, diatoms etc), improved consistency, reduced disturbance to site, greater cost efficiency, and enduring and increased sample access for future analyses. However, as these authors note, the technique at this stage also has some limitations related to DNA sample contamination, efficient sample collection, biases in primer affinity, inability to reliably detect abundances, and deficiencies in reference sequence databases which are currently biased towards larger organisms and some groups.

Waters et al. (2023) recently investigated insect composition and richness in southern streams, comparing eDNA in water samples from forested and deforested reaches. They focused on 89 insect taxa, mostly from cosmopolitan, flighted groups, and found a consistent shift in assemblages, but not richness, between streams with and without forest. More predators occurred in deforested habitats. The widespread and consistent difference demonstrated between forest/deforested riverine zones suggests the technique is potentially useful for monitoring landuse impacts more broadly, on stream condition.

We recommend that ORC use TICI to determine healthy eDNA profiles across i) all wetland types in the region, sampling to cover all relevant FMUs, ii) any repeatedly sampled MCI wetland sites to compare indices, and iii) upstream, within, and downstream from all (or a subset of) regionally significant wetlands.

12. Birds

Many monitoring systems use presence and relative abundance measures, the latter to indicate population-level viability. The most used methodology for monitoring birds in New Zealand is the five-minute bird count (5MBC), occasionally extended in duration depending on recording pattern. Initially developed for monitoring forest birds, the index has been widely used in many habitats, especially by the Department of Conservation. The method provides an index of bird abundance and is useful for long-term trend studies but is subject to considerable interannual variability depending on weather, observer, and habitat (Hartley, 2012). Acoustic monitoring techniques are being used in wetlands, mostly for the presence of indicator taxa (e.g. Australasian bittern (*Botaurus poiciloptilus*), Spotless crake (*Zapornia tabuensis*), and Fernbird (*Poodytes punctatus).*

Bird monitoring may be readily achievable based on annual survey data kept by Fish and Game for game birds in some wetlands. Those birds likely associated with wetlands include Black swan (*Cygnus atratus*), Australasian shoveler *Anas rhynchotis*), Grey duck (*Anas superciliosa*), Mallard duck (*Anas platyrhynchos*), Paradise shelduck (*Tadorna variegata*) and Pukeko (*Porphyrio melanotus*). In lowland wetlands, a focal, threatened, obligate, wetland species could be used as an indicator of wetland habitat condition for birds. The matuku-hūrepo, or brown Australasian bittern (*Botaurus poiciloptilus*) would be a good candidate in Otago lowland wetland complexes.

This year (2024) the NZ Ornithological Society (now Birds New Zealand), in collaboration with the Cornell Laboratory of Ornithology, USA, completed a resurvey of the distribution of birds across New Zealand, last done 20 years ago. The new distributions of birds are available online (NZ Bird Atlas), and although some grid squares in Otago appear to have relatively few observations, and not all private land was accessible, the overall pattern of distribution of most bird species will be reliable. These data can be used to assess changes in range (not abundance) of focal wetland species, augmented by targeted local assessments of specific wetlands. Overall, five-yearly assessment at these two scales should allow trends to be detected, although the causes of any change will likely reflect a combination of predator control and habitat health.

13. Proposal

Considering the requirements of the NPS FM 2020, national environmental policy and reporting commitments, and current ORC policies on wetlands, we propose a three-tier monitoring system for wetlands in Otago. This recognises the relevant stresses on wetlands at different scales, the need for on-site condition assessments, and the large diversity and number of wetlands in the region. Throughout we develop metrics that will allow ORC to assess changes in threat level (Stressors) for wetlands to guide policy development, while also providing metrics for wetland extent and condition for vegetation type and FMU, to aid both policy formation and local management decisions. Overall, we follow Clarkson et al. (2003) which is used by many Regional Councils and supported by the Ministry for the Environment. However, we expand their framework and narrow the focus to include what we consider as major threats, acute and chronic, to wetlands in Otago, and attempt to provide metrics that are consistent, measurable, and informative.

A major advantage in New Zealand is that a standardised classification has already been applied to wetlands, which removes this objective from the condition assessment measurements. As mentioned earlier, our major departure from Clarkson et al. (2003), and most overseas wetland monitoring frameworks (e.g. Dorney et al. 2018), is to remove the need to find a benchmark or ideal reference site, and instead use general features that characterise all wetlands, irrespective of their type, namely dominance of native biota and protection of threatened indigenous species. This recognises the largely unknown prehuman and human history, the inherently dynamic features, and the uncertainty of responses to changing environment of these ecosystems.

14. Wetland Condition Index Framework

The standard methodology for monitoring wetlands in New Zealand was established by Clarkson et al. (2003) and this is being applied by many regional councils, commonly known as the Wetland Condition Index (WCI). We understand that modifications are occurring and that MfE will eventually have a standardised monitoring methodology for Councils. However, in the interim, ORC requires an initial monitoring system to report on condition and extent of representative wetlands in Otago.

The WCI tool was developed before the NPS FM 2020 became operative but provides a useful starting basis for assessing wetland condition in the current context, although wetland extent and threatened species, highlighted in the NPS, are not considered. We address these issues following consideration of the WCI.

In this section we go through all the indicators recommended by Clarkson et al. (2003) and briefly discuss their relevance and suitability for inclusion in the NPS FM 2020 monitoring programme in Otago. At this stage we exclude discussion of the numerical index, which is a separate exercise, and dependent on the ultimate selection of specific variables, although the Clarkson et al. (2003) scores provide a potential framework.

The WCI comprises five semi-independent wetland condition indicators that measure change in hydrological integrity; physicochemical parameters; ecosystem intactness; browsing, predation and harvesting regimes; and dominance of native plants. The indicators are derived from a mix of plot-based measurements of water, soil, and vegetation characteristics and general assessments of multiple variables, and each has several components that are measured.

14.1 Indicators

Hydrological Integrity – Maintaining the current hydrological regime is essential for sustaining all types of wetlands, especially those that are associated with rivers, streams, runoff, springs, and ground water. Three components are recognised (H1-H3):

H1- Impact of man-made structures that alter hydrological regime: This refers to a range of structures, from drains in or around wetlands, dams or weirs, and water abstraction near the wetland. The WCI aggregates these qualitatively into a single measure but we recommend for the Otago region identifying at least two quantitative metrics,

i. proportion of wetland, including edge, influenced by drains, dams etc. and
ii. number, offtake level, distance from wetland of water abstraction activities.

Some wetland types, such as ephemeral wetlands, are dependent on precipitation and associated groundwater inputs, usually in winter, to maintain their biota, and rainfall patterns will not be modified directly by human activities. Likewise, lowland coastal wetlands may become increasing saline as tidal levels rise, often facilitated by man-made structures that restrict impoundment areas, but these changes will shift wetland vegetation types rather than alter wetland condition.

H2 - Change in water table depth: In many wetland types, water tables fluctuate seasonally and often over shorter timescales, and the link between these changes and the composition and structure of the vegetation, assuming they are at some level of equilibrium, varies. Few wetlands have regularly monitored water table levels and spot checks of representative examples would be useful but difficult to compare over time. We have used permanent capacitor probes to measure water levels in ephemeral wetlands, with data downloaded annually, and these could be usefully deployed in a network of representative wetland types, particularly those in largely agricultural, horticultural or forestry-intensive landscapes where potential changes in water table levels could occur.

i. Depth to water table measured in plots is supported.

H3 - Dryland plant invasion: The WCI includes both indigenous and exotic species in this component as indicators of both changing hydrological regimes and a decline in wetland vegetation condition with the invasion of potential woody weeds. The relative dominance of dryland exotic species is an indication of longer-term (i.e. interannual) changes in water regime and can be determined from the cover and composition data obtained from plots in different plant communities. The categorisation of indigenous and exotic species according to their soil moisture tolerance and preferences is provided by Clarkson et al. (2013) and updated in Clarkson et al. (2021). This measure is appropriate for obligate wetland habitats. However, many lowland and montane wetlands in the region are complex, composite ecosystems, with a range of wetland types and distinct habitats, including relatively dry levees, gravel and sand accumulations, and small ridges. These naturally drier sites could support dryland species, both native and indigenous. In these micro-habitats we are less concerned about the establishment of indigenous dryland species, as these may reflect restoration of original communities or new trajectories for the system. So long as this is understood in interpreting patterns of change, we support using any increase in dryland species at the plot level as a relevant indicator.

i. Percentage of obligate dryland taxa (species and cover) in the plots.

Physico-chemical parameters **–** These include impacts on wetlands from adjoining activities, and disturbances associated with fire that limit plant growth and modify habitats for plants and other biota.

P1 Fire damage: Fire is a feature of wetlands in New Zealand, both natural and human-induced, as indicated from charcoal deposits and the presence of serotinous populations of *Leptospermun* *scoparium* on some wetlands. However, fire opens habitats to invasion by shrub weeds, destroys surface layers of peat, and exterminates many fire-sensitive biota. It also reduces structural complexity of wetland systems, removing the woody components that are often scare regionally. For wetlands, resilience increases with time since last fire. We suggest that wetland fire histories should be assessed, where these are known, using time since last fire as the main metric. Where uncertain, wetland fire histories, can be benchmarked at 10 years, fire-free. Overall, a new metric is supported based on

i. time since last fire for individual wetlands monitored, and
ii. number of wetland polygons burnt in past 1, 2-5, 6-10, 11-20, and 21 years at the wetland type and FMU level.

P2 Degree of sedimentation/erosion: Sediment deposition in many wetland types will modify hydrological regimes and create local drier habitats. Fresh sediments can reflect changing stream courses, stream-bank erosion, hill-country erosion following deforestation, and regional tectonic movement, and can impact peat wetlands, in particular. However, the input of sediment is a natural part of wetlands such as swamps, such that the substrate is typically a mixture (sometimes in layers) of peat and silt. In contrast, seepage areas and fens are less affected by local sediment deposition. In our experience in Otago, we are less concerned about fresh sediment arrival in most wetland types, partly reflecting the general landscape stability on schist substrates across the region, and the large extent of most wetlands. The focus, in our view, should be on enhanced local sediment loadings. Locally, mining, roading, suburban developments, plantation forestry harvesting, and other infrastructural activities may move and release sediment pulses into waterways that can impact wetlands downstream, but most of these activities require consents which should necessitate mitigation of potential negative environmental impacts. The extent of roading in a catchment has been used elsewhere as a potential stressor for risk of sedimentation, but in New Zealand multiple projects can create sediment pulses and measuring a single type may not be useful.

P3 Nutrient levels: Nitrogen and phosphorus spillover from intensive agriculture and farmland can alter the nutrient status of wetlands, fostering transitions to alternative vegetation types and consolidating weed infestations adapted to more eutrophic ecosystems. This is a major issue in Waikato peat bogs dominated by regionally endemic species surrounded by intensive dairy farming. In our view the problem is potentially also widespread here in Otago. Vulnerable area in a matrix of intensive agriculture and pasture development is influencing the scroll plains and wetlands associated with the upper and lower Taieri catchment, swamps in SE Otago, and parts of mid-altitude Central Otago. Increasingly, agricultural fertilizer from runoff, as well as blanket aerial topdressing is occurring in lowland-montane bog and fen systems, particularly where extant wetlands occupy valleys and depressions within a matrix of land that is being progressively altered to pasture at increasing altitudes.

Clarkson et al. (2003) advocate monitoring foliar nutrient levels to detect shifts in nutrient inputs, but the results, in our experience, are difficult to interpret, vary across species, and do not matter if indigenous species continue to dominate the wetland. Many of the wetlands along the Taieri and Waipori catchments, for example, are already relatively nutrient-rich systems. However, we suggest soil water samples be included in regular monitoring at the plot level and analysed for phosphorus and nitrogen. These reflect nutrient regimes across the wetland and are generally more reliable than either soil/peat or plant samples.

i. Nitrogen and phosphorus determined in soil water samples at plot level.

P4 von Post Index (Peat bogs only): This index was developed to assess peat decomposition, especially signs of degradation that might confirm shifts in water table or major changes in vegetation associated with fire or other disturbance types. In our view this measure is not essential in Otago where we have a range of peat and non-peat wetland types, and mixtures of both categories in a single wetland. Clarkson et al. (2003) note that the index is a simple measure and perhaps it is more relevant to monitor the loss of peat forming species, such as *Sphagnum*, which would be a useful measure in Otago bogs and fens where invasive species such as browntop (*Agrostis capillaris*) can out-compete the moss. The von Post Index is not suggested for Otago.

An alternative metric assessing ongoing peat formation potential is measuring the cover and number of peat-forming species in the wetland. In Otago these could be identified and using information from plot sampling, formulated into an assessment measure, where relevant.

Ecosystem intactness **–** Functional linkages between and within wetlands are important for sustaining biodiversity but the requirements for plants and animals are often scale-dependent. Clarkson et al. (2003) identify size, local wetland loss, and the presence of stream modification as factors decreasing wetland viability and local population sizes. We would add the presence of indigenous vegetation buffer zones adjoining the wetland and the area and number of other wetlands in the catchment to increase the diversity and viability of propagules available to colonise, sustain and facilitate wetland habitats. This measure would best be associated with the assessment of wetland extent, discussed later.

E1 Loss in area of original wetland: The delineation of current wetlands in Otago recognised historic loss of these habitats in defining extant wetlands, but we are uncertain whether including this factor in condition assessments is useful because of the low likelihood of areas now drained, raised, cleared of native vegetation, and repurposed, ever being wetlands again. Decrease in area does increase wetland vulnerability and this is a general stressor that could be more appropriately included in the wetland pressure index (discussed later) if it could be confidently calculated at the individual wetland scale. The measure would mostly apply to larger lowland wetlands.

E2 Connectivity barriers: Clarkson et al. (2003) refer to any barriers, upstream or downstream, that impacts access by stream biota to the wetlands, limiting population survival and recovery of many mobile fish and invertebrates. In many instances, the proximity of these structures to the wetland would be important for assessing relevance, and only small structures would likely change over time. We recommend the following measures:

i. number and area of wetlands upstream in the catchment,
ii. proportion of catchment in indigenous vegetation,
iii. ratio of indigenous non wetland/wetland habitat at the site, and
iv. the proportion of upstream reaches having indigenous riparian vegetation might be more important.

Higher values for these measures would be used in the pressure index to indicate greater connectivity in the landscape and therefore increased resilience and reduced stress on the wetland.

***Browsing, Predation and harvesting regimes* –** The removal of indigenous species by predators, herbivores and humans modifies wetland composition, habitat structure and hydrological processes in many wetlands. Stock, especially cattle and deer, can reduce indigenous plant dominance and successional development, while compacting soils and peat causing water ponding and enhanced erosion and runoff. Sheep are less impactful on soils but preferentially graze herbaceous species, both introduced and indigenous, and limit succession. Feral animals such as goats also consume vegetation, and pigs may turnover large areas around wetland margins extracting roots, mushrooms etc. Mammalian predators are also pervasive, and are responsible for the loss of avian, lizard, and many invertebrate species in these habitats. Birds, both introduced and indigenous, are less detrimental for wetland ecosystems in New Zealand, reflecting our long history of avian dominance in the landscape. Numerous indigenous plants, for example, have prostrate habit and their abundance locally is maintained by bird grazing.

Currently game birds, tuna, galaxiids, and trout are seasonally harvested from some coastal and larger wetlands. Sphagnum moss may also be taken from some wetlands in Otago.

B1 Damage by domestic/feral animals: The Resource Management Stock Exclusion Regulations (2020) requires all wetlands to be fenced to exclude stock, so direct damage by domestic animals should be much reduced in future. Even following fencing, feral animals unimpeded by fences will remain widespread and continue to impact wetlands. Also, the large number and remote location of many wetlands in upland Otago will make it impractical to fence all wetlands. However, under extensive pastoralism, wetlands are often preferred habitats for stock and feral animals, particularly in drier regions. We suggest that in these situations, evidence of herbivore impacts is the primary feature to be monitored as it directly impacts wetland condition. Clarkson et al. (2003) recommend an area measure for the entire wetland reflecting presence of stock/feral animal sign, and we support this.

i. Extent of trampling/digging by feral animals on wetland.
ii. Browse sign on vegetation.

B2 Introduced predator impacts on wildlife: Introduced mammalian predators are pervasive in Otago and several wetlands near Dunedin are under active, intensive predator control, often supported by community groups. At the landscape scale, OSPRI NZ have large scale programmes removing some mammalian predators (mainly possum) to limit spread of bovine TB, and locally include other vectors such as stoats, ferrets, and pigs. Predator Free 2050 have similar ambitions and currently have community groups involved in several parts of Otago. Clarkson et al. (2003) use a combination of aerial extent, type and regularity of predator control programmes, and level of potential reinvasion, to measure predator impacts, along with evidence of predator presence, such as scats etc. This is a complex measure and difficult to quantify. We suggest that two independent measures are used at the wetland level, with the first also repeated at the catchment level:

i. active, regular possum and mustelid predator control programme
ii. rodent control programme

B3 Harvesting of biota: The use of wetlands for recreational purposes is advocated under the NPS FM 2020 and currently game birds, tuna, galaxiids, and trout are seasonally harvested from some coastal and larger wetlands. Clarkson et al. (2003) have a combined impact measure, a generic harvesting regime assessment that is not directly transferable to assessing condition in the NPS FM (2020). We suggest several metrics facilitate reporting on both human uses of wetlands and potential impacts of harvesting. The metrics on gamebirds could be provided by Fish and Game (Otago) who keep good records of gamebird distribution and hunting activity at some of the larger wetlands in the region. Harvesting consents are controlled by the Department of Conservation (we think) who could provide data for wetland habitat areas. The suggested metrics include:

i. gamebird richness in the wetland and active seasonal hunting.
ii. fish harvesting offtake (e.g. tuna and galaxiids).
iii. Any other harvesting (e.g. harvesting of *Sphagnum* moss which has occurred in the past).

Dominance of native plants –

D1 Introduced plant canopy cover - Wetlands are threatened by many invasive introduced woody species, some intentionally established in past decades to strengthen water courses and limit bank erosion (e.g. *Salix, Alnus* spp.) but others are invading from adjoining amenity plantings (e.g. *Betula pendula*). Taking the Clarkson et al. (2003) list of wetland weeds relevant to the Otago Region (Appendix 2), we provide a shortened list of major weeds that will dominate and displace indigenous species, high-jacking the wetland and creating an alien (likely northern-hemisphere analogue) ecosystem. The most serious weed species are often woody and their presence and extent across a wetland can be assessed using ground inspections or in some cases from aerial photographs. However, species such as reed sweetgrass (*Glyceria maxima*) will require field inspections. Clarkson et al. (2003) use a combination of number of taxa and cover, but in our view, it would be more useful to separate these for any assessment of condition. Also, it is unclear whether the measure is derived from the entire wetland, which is preferable, or the plot measurements which are limited. Our suggested metrics at the wetland scale are:

i. number of wetland-weed taxa present.
ii. proportion of wetland covered by wetland-weed taxa.

D2 Introduced plant understory cover: Several herbaceous species are also invasive and can dominate wetland habitats where they have major impacts. In our experience, many areas of upland and inland Otago remain relatively free of these invasive weeds, highlighting the importance of surveillance to detect founding populations when eradication is both possible and cost-effective. Understory introduced taxa are likely to be herbaceous. During early phases of invasion, weed distribution is likely to be patchy on the wetland and unlikely to be detected in plot sampling. We suggest their presence and extent across a wetland can be assessed using ground inspections or from aerial photographs or extrapolated from plot data.

For this measure, Clarkson et al. (2003) use cover in the understory. We suggest in Otago that differentiating canopy and understory weeds is not applicable because most wetlands have a simple vegetation structure, lacking shrubs or trees, and that wetland-weeds are often common across a range of wetland habitats. We support using the same metrics as identified in the canopy, namely:

i. number of wetland-weed taxa present.

ii. proportion of wetland covered by wetland-weed taxa.

Indigenous plant and bird dominance: We also suggest an additional component that measures the relative dominance of indigenous species in wetland ecosystems, thereby controlling key functional processes and services. This is a core basis for condition assessments and fundamental for assessing conservation outcomes and management initiatives. Initially, we suggest that plants and birds could be included but other experts and new techniques need to be considered, as fish and some invertebrates could also be included. For plants the wetland and plot scale assessments are essential and for birds we suggest the wetland scale for primary assessment. As for threatened plant species, we suggest presence/absence on the wetland as the primary measure for both obligate wetland and more generalist bird species, and initially occupancy data could be taken from the new NZ Bird Atlas.

We suggest the following metrics for native plants:

i. Proportion of wetland with native species cover

ii. Number of native species present

For birds we suggest:

i. Number of native species present

ii. Number of obligate wetland bird species present

15. Additional Wetland Condition Features required by NPS FM 2020

Several additional factors, not considered explicitly by Clarkson et al. (2003) are required to be assessed as part of the wetland condition index for the NPS FM (2020). These are wetland extent and the status of any threatened species.

Extent **-** In our view, "extent" refers to both the number and size of natural wetland habitats in each of the wetland types represented in a Freshwater Management Unit, and across the region. Both the number and extent of estuarine and lowland wetlands can increase over time as sea-level rises, influencing lowland and coastally connected systems. The occasional extreme rainfall event may also reconfigure the landscape, occasionally creating new wetlands. Farmers may establish new juvenile wetlands as part of on-farm water containment, and developers may establish wetlands for mitigation under the Resource Management Act. However, the focus of the NPS FM (2020) is the ongoing loss of existing wetlands. We recommend that changes in the number and size of wetlands across Otago could be determined using the same techniques as employed by Wildlands Consultants (Lloyd et al. 2020) to establish the current number, extent, and type of wetlands. Perhaps the exercise could be repeated at decadal intervals, either to cover all or part of each FMU. We are also aware of advances in satellite imagery that may assist this process. Recently, Dymond et al (2021) used a combination of LCDB and the WONI to re-examine the extent of wetlands in New Zealand and this process could be repeated to assess change in wetland extent.

The suggested measure is:

i. Number and area of wetlands according to FMU and wetland type.

Threatened species presence – The distribution and management of threatened indigenous species is a national responsibility of the Department of Conservation. DoC creates the official list of threatened taxa and maintains a distributional data base. Where threatened species (plants, fungi or animals) are known to occur in a particular wetland, their presence/absence should be confirmed during monitoring. Abundance information is useful but time-intensive to obtain, and a cover estimate across the wetland would suffice for plants. However, in our view, the presence of a species across multiple wetlands is likely a more reliable indicator of species viability. We suggest that the plant and animal threatened species lists be used to identify obligate and facultative wetland species focussing on those with core distributions in the Otago region. The following measures are suggested:

i. number of threatened species present in wetland.

ii. number of wetlands occupied by focal threatened species.

In summary, we suggest the following features of wetlands could be used to indicate high ecological integrity or condition.

- Sustained hydrological regime.
- Presence of obligate wetland animal species (e.g. birds, galaxiids).
- Dominance of indigenous plant species.
- Status of threatened species.
- No ecosystem-capturing introduced weeds.
- Fenced to exclude stock-grazing.
- Active predator control programme for introduced mammalian predators.
- Adequate buffering from surrounding landuse.

16. Wetland Pressure Index

Clarkson et al. (2003) list six indicators reflecting potential threats to wetland condition that reflect the landscape context and boundary features of the wetland. These are considered pressures or stressors on the wetland ecosystem with potential to impact on habitat drivers and biota. These include modifications to catchment hydrology, water quality within the catchment, animal access, key invasive exotic species, percentage of the catchment in introduced vegetation, and other pressures.

Although wetlands are discrete and recognisable habitats in the landscape, they are impacted by factors at the catchment scale where drainage patterns, extent of indigenous cover, and level and type of agriculture intensification may influence the current and future extent and condition of the wetland. Collectively, these factors represent catchment stressors and aggregate the cumulative changes resulting from land use shifts across the catchment. Most can be assessed from LCDB data layers or aerial photographs. Measurements can be scaled to the Freshwater Management Unit, depending on the number of catchments included for measurements.

We identify three pressures that impact wetlands: natural character, intensive agriculture and forestry, and water abstraction from the catchment. At the catchment level, the proportion of area supporting non-native vegetation, intensive agriculture, and plantation forestry presents a threat to the wetland through disturbance, nutrient spillover, depleted functional links to sustain biota, source of invasive weed species, and periodic major sedimentation events. Measuring these factors will enable the interpretation of drivers behind any changes in wetland conditions and identify relevant policies or regulations to limit threats in the future.

The extent and location of indigenous vegetation in the catchment is likely to sustain hydrological regimes, notably rainfall, interception, surface runoff and groundwater, ensure availability of seed sources for suitable species for successional development and ecotonal habitats, and provide corridors for movement of biota across the landscape with wetlands. The converse, that is area dominated by non-native vegetation, potentially limits these benefits. The relative area of intensive agriculture provides a source of weeds and nutrients that modify and degrade wetlands, while plantation forestry captures water in many eastern environments and may pose sediment and slash risks for downstream wetlands. Finally, the amount of water taken for urban or agricultural requirements also may deprive wetlands of a fundamental driver.

We suggest the following metrics at the catchment scale for assessing wetland pressures or stressors.

i. Size of catchment (hectares) and elevation range (m) upslope and upstream from the wetland.
ii. Proportion of catchment, riparian zones along rivers/streams, and wetland borders in non-native vegetation.
iii. Proportion in agriculture, separating low and high intensity agriculture based on stocking rates and fertiliser inputs.
iv. Proportion of catchment in plantation forestry.
v. Number and size of active water extraction consents for rivers/streams/groundwater.

17. Conclusions

In our view, a relevant and effective monitoring system focuses on the both the values identified for protection and the major threats to these in the area. Monitoring threats is relevant because it guides the formulations of policies and regulations. For biodiversity in general, monitoring can be challenging because of the numerous components, diverse values, multiple threats, and the natural dynamics of most ecosystems. However, the NPS FM 2020 sets out the values of interest regarding wetlands and provides a clear context for developing a wetland condition and extent monitoring framework.

In our view enhanced wetland condition means increasing dominance of native species, including birds, plants, fish and invertebrates, and reduced threats from plant and animal pests, and encroaching landuse that reduces water quality and quantity in the wetland. The framework we suggest has a combination of inhouse and field measurements, and these are indicated in Table 1, along with the appropriateness of the indicators for condition or pressure measures. We attempted to keep indicators exclusive to either WCI or WPI but recognise that in some instances they can reasonably be assigned to both. In this report we have not developed an explicit scoring system, as per Clarkson et al. (2013) as this would depend on which indicators are adopted. However, we would advocate a three-category score, to decrease observer variance and ambiguity. We would also suggest that ORC trial these indicators on selected wetlands in Otago with the relevant information to assess their utility and develop a reporting format at the FMU level. We would be willing to assist in this exercise, if useful.

18. Acknowledgements

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***Table 1** - Wetland Condition Index and Wetland Pressure Index Framework. Modification of Clarkson et al. (2003), showing indicator, component, scale of measurement and relevance for either WCI or WPI. Whether data involves field work or can be accessed from the office using existing databases is also indicated.*

Indicator	Components	Metrics	Measurement Scale			WCI	WPI	Data Source	
			Catchment	Wetland	Plot			Office	Field
Wetland Condition									
Hydrological Integrity	Impact of man-made structures of hydrological regime	Proportion of wetland, including edge, influenced by drains, dams etc.		X		X			X
		Number, offtake level, distance from wetland of water abstraction activities.	X				X	X	X
	Change in water table depth	Depth to water table measured in plots is supported.			X	X			X
	Dryland plant invasion	Percentage of obligate introduced dryland taxa (species and cover).		X	X	X			X
Physico-chemical Integrity	Fire frequency	Time since last fire for individual wetlands monitored		X		X		X	X
		Number of wetland polygons burnt in past 1, 2-5, 6-10, 11-20, and 21 years at the wetland type and FMU level.	X	X		X		X	X
	Degree of sedimentation erosion	Not measured							
	Nutrient levels	Nitrogen and phosphorus in soil water			X	X			X
	von Post index	Not measured							
Ecosystem intactness	Loss in area of original wetland	Not measured							
	Connectivity and buffering	Number and area of wetlands upstream in the catchment.	X				X	X	

		Proportion of catchment in indigenous vegetation.	X				X	X	
		Ratio of indigenous non wetland/wetland habitat at the site.		X	X	X		X	
		Proportion of upstream with indigenous riparian vegetation might be more important	X				X	X	
Browsing, predation and harvesting regimes	Damage by feral/domestic animals	Extent of trampling/digging by feral animals on wetland		X		X			X
		Browse sign on vegetation.		X	X	X			X
	Introduced predator impacts on wildlife	Active, regular possum and mustelid predator control programme		X			X	X	
		Rodent control programme		X			X	X	
	Harvesting of biota	Gamebird richness in the wetland and active seasonal hunting		X			X	X	
		Fish harvesting offtake (e.g. tuna and galaxiids).		X			X	X	
		Any other harvesting		X			X		X
Dominance of native species	Native plants	Proportion of wetland with native species cover		X	X	X			X
		Number of native species present				X			X
	Native birds	Number of native species present				X			X
		Number of obligate wetland bird species present				X			X
	Introduced weed cover	Number of wetland-weed taxa present.		X	X	X			X
		Proportion of wetland covered by weed taxa.		X	X	X			X

Wetland – threatened species and extent									
Threatened species	Status of threatened species in wetlands	Number of threatened species in wetland		X		n/a	n/a	X	X
		Number of wetlands supporting threatened species	X	X		n/a	n/a	X	
Extent	Number and extent of wetlands	Number and area of wetlands according to FMU and wetland type	X			n/a	n/a	X	

Appendix I

Regional Plan: Water for Otago Otago Regional Council Updated to 5 March 2022

Policies related to the maintenance and enhancement of wetlands in Otago that could be evaluated under the NPS for the Freshwater Management (2020) wetland monitoring programme.

10.3 Objectives

10.3.1 Otago's wetlands and their individual and collective values and uses will be maintained or enhanced for present and future generations.

10.3.2 Otago's Regionally Significant Wetlands and their values and uses are recognised and sustained.

10.4 Policies

10.4.1 Otago's regionally significant wetland values are:

A1 Habitat for nationally or internationally rare or threatened species or communities;

A2 Critical habitat for the life cycles of indigenous fauna which are dependent on wetlands;

A3 High diversity of wetland habitat types;

A4 High degree of wetland naturalness;

A5 Wetland scarce in Otago in terms of its ecological or physical character;

A6 Wetland which is highly valued by Kai Tahu for cultural and spiritual beliefs, values and uses, including waahi taoka and mahika kai;

A7 High diversity of indigenous wetland flora and fauna;

A8 Regionally significant wetland habitat for waterfowl; and

A9 Significant hydrological values including maintaining water quality or low flows or reducing flood flows.

10.4.6 To promote the conservation, creation and reinstatement of wetland areas and enhancement of individual and collective wetland values by:

(a) Educating Otago's people and communities about land use activities

that may affect wetlands and their values;

(b) Promoting the fencing of wetlands;

(c) Initiating or supporting investigations and monitoring of wetlands

and their values;

(d) Supporting voluntary community and landholder programmes;

(e) Initiating or undertaking works in consultation with local

communities;

(f) Providing information on wetlands and their values; or

(g) Providing for the restoration or enhancement of wetlands and wetland values

10.4.8 The loss of natural inland wetlands is avoided, their values are protected, and their restoration is promoted, except where:

(a) The loss of extent or values arises from any of the following:

(i) The customary harvest of food or resources undertaken

in accordance with tikanga Maori

(ii) Restoration activities

(iii) Scientific research

(iv) The sustainable harvest of sphagnum moss

(v) The construction or maintenance of wetland utility structures (as defined in the Resource Management (National Environmental Standards for Freshwater) Regulations 2020

(vi) The maintenance or operation of specified infrastructure, or other infrastructure (as defined in the Resource Management (National Environmental Standards for Freshwater) Regulations 2020

(vii) Natural hazard works (as defined in the Resource Management (National Environmental Standards for Freshwater) Regulations 2020; or

(b) The regional council is satisfied that:

(i) The activity is necessary for the construction or upgrade of specified infrastructure; and

(ii) The specified infrastructure will provide significant national or regional benefits; and

(iii) There is a functional need for the specified infrastructure in that location; and

(iv) The effects of the activity are managed through applying the effects management hierarchy.

Appendix II

Otago Wetland Weeds - Lists of naturalised (non-native) plants of known or likely occurrence on Otago Wetlands

Compiled by Peter Johnson

These lists have been prepared for Otago Regional Council as a contribution to the planning of wetland condition monitoring.

The first tabled list is derived from:

Clarkson BR, Fitzgerald NB, Champion PD, Forester L, Rance BD 2021. New Zealand wetland plant list 2021. Manaaki Whenua - Landcare Research contract report LC3975 for Hawke's Bay Regional Council.

That national list, prepared to assist councils and the wider public in delineating wetlands, embraces both native and naturalised plant species known to occur in New Zealand wetlands, with each species categorised as to its 'wetland status', that is the degree to which it is an obligate wetland plant (always in wetlands) or facultative (sometimes in wetlands), and with finer divisions as follows:

- OBL: Obligate Wetland. Almost always is a hydrophyte, rarely in uplands (non-wetlands).
- FACW: Facultative Wetland. Usually is a hydrophyte but occasionally found in uplands.
- FAC: Facultative. Commonly occurs as either a hydrophyte or non-hydrophyte.
- FACU: Facultative Upland. Occasionally is a hydrophyte but usually occurs in uplands.
- UPL: Obligate Upland. Rarely is a hydrophyte, almost always in uplands.

Table 2 (below) lists wetland weed species of known or likely occurrence in Otago. Whereas the national list has some 363 'exotic' (or naturalised) species, this Otago list totals 134. In compiling the Otago list we have not included any plant species categorised as UPL (obligate upland/ non-wetland) partly on the basis that these entities did not seem useful to list in the Otago context, and also because there can be, in particular wetland sites, any number of weed species that can make an occasional presence on raised, drier ground within a wetland.

In Table 2 the left column (#) refers to the listed number in the national list, included here for back-reference as users might wish), and a column 'JB no.' which provides a 'further information' link to wetland species described and illustrated (by that common refence number) in Johnson and Brooke (1989) *Wetland Plants in New Zealand*.

Otago Regional Council

Table 2 - Lists of naturalised (non-native) plants of known or likely occurrence on Otago Wetlands

#	Plant species	Common name	Wetland status	JB no.
21	*Agrostis capillaris*	browntop	FACU	257
23	*Agrostis stolonifera*	creeping bent	FACW	257
26	*Alisma lanceolatum*	water plantain	FACW	34
27	*Alisma plantago-aquatica*	water plantain	OBL	33
29	*Alnus glutinosa*	alder	FACW	430
32	*Alopecurus geniculatus*	kneed foxtail	FACW	251
44	*Anthoxanthum odoratum*	sweet vernal	FACU	
6	*Atriplex prostrata*	orache	FACU	
78	*Barbarea intermedia*	winter cress	FAC	300
81	*Bellaria viscosa*	tar weed	FAC	
86	*Betula pendula*	silver birch	FAC	
106	*Buddleja davidii*	buddleia	FACU	
120	*Callitriche stagnalis*	starwort	OBL	380
127	*Calystegia silvatica*	great bindweed	FACU	
133	*Cardamine pratensis*	lady's smock	OBL	305
148	*Carex demissa*	yellow sedge	FACW	206
152	*Carex divisa*		FAC	235
159	*Carex flacca*	blue sedge	FACW	212
171	*Carex leporina*	oval sedge	FACW	238
207	*Carpobrotus chilensis*	sea fig, ice plant	FACU	
219	*Centauriun erythraea*	centaury	FACU	473
228	*Cerastium fontanum*	mouse-ear chickweed	FACU	
229	*Cerastium glomeratum*	mouse-ear chickweed	FACU	
251	*Cirsium arvense*	Californian thistle	FACU	
252	*Cirsium palustre*	marsh thistle	OBL	470d
253	*Cirsium vulgare*	Scotch thistle	FACU	
261	*Conium maculatum*	hemlock	FAC	
296	*Cortaderia selloana*	pampas	FAC	
313	*Crepis capillaris*	hawksbeard	FACU	
329	*Cyperus eragrostis*	umbrella sedge	FACW	139
334	*Cytisus scoparius*	broom	FACU	
337	*Dactylis glomerata*	cocksfoot	FACU	
382	*Elodea canadensis*	Canadian pondweed	OBL	37
395	*Epilobium ciliatum*	willowherb	FAC	375
409	*Equisetum arvense*	horsetail	FACU	16
411	*Erica lusitanica*	Spanish heath	FACU	
415	*Erythranthe guttata*	monkey musk	OBL	509
416	*Erythrathe moschata*	musk	OBL	510

439	*Festuca rubra*	Chewings fescue	FACU	
459	*Galium palustre*	marsh bedstraw	OBL	431
490	*Glyceria declinata*	glaucous sweetgrass	OBL	248
491	*Glyceria fluitans*	floating sweetgrass	OBL	247
492	*Glyceria maxima*	reed sweetgrass	OBL	246
493	*Glyceria plicata*	sweetgrass	OBL	248a
507	*Gunnera tinctoria*	Chilean rhubarb	FAC	365a
519	*Hesperantha coccinea*	Kaffir lily	FACW	125
528	*Holcus lanatus*	Yorkshire fog	FAC	254
547	*Hypericum humifusum*	trailing St Johns wort	FAC	387
554	*Hypochaeris radicata*	catsear	FACU	
558	*Iris pseudacorus*	yellow iris	OBL	124
575	*Isolepis marginata*		FAC	163
581	*Isolepis setacea*		FACW	161
584	*Jacobaea vulgaris*	ragwort	FACU	
585	*Juncus acuminatus*	sharp-fruited rush	OBL	85
586	*Juncus acutiflorus*	sharp-flowered rush	FACW	83
588	*Juncus amabilis*		FACU	100
590	*Juncus articulatus*	jointed rush	FACW	82
593	*Juncus bufonius*	toad rush	FACW	76
595	*Juncus bulbosus*	bulbous rush	OBL	79
598	*Juncus conglomeratus*		FACW	96
601	*Juncus effusus*	soft rush	FACW	94
602	*Juncus effusus var. compactus*	soft rush	OBL	94a
604	*Juncus ensifolius*	iris-leaved rush	FACW	78
605	*Juncus filicaulis*		FAC	103
608	*Juncus gerardii*	saltmarsh rush	FACW	74
610	*Juncus inflexus*	hard rush	FACW	102
613	*Juncus microcephalus*		FACW	90
619	*Juncus procerus*		FACW	92
624	*Juncus squarrosus*	heath rush	FACW	77
625	*Juncus subnodulosus*		FACW	84
626	*Juncus tenuis*	track rush	FACU	75
637	*Lagarosiphon major*	lagarosiphon	OBL	38
643	*Leontodon saxatilis*	hawkbit	FAC	
671	*Linum catharticum*	purging flax	FAC	351
730	*Mentha pulegium*	pennyroyal	FAC	523
731	*Mentha spicata*	spearmint	FAC	524
733	*Mentha suaveolens*	apple mint	FACU	527
735	*Mentha X piperita*	peppermint	FACW	525
736	*Menyanthes trifoliata*	bogbean	OBL	488
759	*Mycelis muralis*	wall lettuce	FACU	

761	*Myosotis arvensis*	field forget-me-not	FACU	
762	*Myosotis discolor*	grassland forget-me-not	FACU	490
764	*Myosotis laxa subsp caespitosa*	water forget-me-not	OBL	489
765	*Myosotis scorpioides*	water forget-me-not	FACW	490a
777	*Nardus stricta*	mat grass	FAC	
778	*Nasturtium microphyllum*	watercress	OBL	303
779	*Nasturtium officinale*	watercress	OBL	304
790	*Nymphaea alba*	white water lily	OBL	297
814	*Oxalis corniculata*		FACU	
823	*Paspalum dilatatum*	paspalum	FACU	
828	*Paspalum vaginatum*	saltwater paspalum	FACW	
830	*Persicaria hydropiper*	water pepper	OBL	334
831	*Persicaria lapathifolia*		FAC	
832	*Persicaria maculosa*	willow weed	FACW	
836	*Phalaris aquatica*		FAC	
837	*Phalaris arundinacea*	reed canary grass	FACW	243
839	*Phleum pratense*	timothy	FACU	
849	*Pilosella officinarum*	mouse-ear hawkweed	FACU	
866	*Plantago australis*	swamp plantain	FAC	480c
867	*Plantago coronopus*	buck's horn plantain	FAC	475
868	*Plantago lanceolatus*	narrow-leaved plantain	FACU	
870	*Plantago major*	broad-leaved plantain	FACU	474
880	*Poa annua*	annual poa	FACU	256
884	*Poa pratensis*	Kentucky blue grass	FACU	256a
885	*Poa trivialis*	rough stalked meadowgrass	FACU	
890	*Polygonum aviculare*	wireweed	FAC	
891	*Polypogon monspeliensis*	beard grass	FAC	255
895	*Potamogeton crispus*	curly pondweed	OBL	52
898	*Potentilla anglica*	creeping cinquefoil	FAC	395a
903	*Prunella vulgaris*	selfheal	FACU	521
915	*Puccinellia distans*	reflexed salt grass	FACW	264
916	*Puccinellia fasciculata*	salt grass	FACW	263
922	*Ranunculus acris*	meadow buttercup	FAC	292

928	*Ranunculus flammula*	spearwort	FACW	276
942	*Ranunculus repens*	creeping buttercup	FAC	289
943	*Ranunculus sardous*	hairy buttercup	FAC	291
944	*Ranunculus sceleratus*	celery-leaved buttercup	OBL	275
947	*Ranunculus trichophyllus*	water buttercup	OBL	277
958	*Rorippa sylvestris*	creeping yellow cress	FAC	301
996	*Salix X fragilis*	crack willow	FACW	426
997	*Salix X reichardtii*	pussy willow	FACW	429
1030	*Solanum dulcamara*	bittersweet	FAC	
1031	*Solanum nigrum*	black nightshade	FACU	
1032	*Sonchus arvensis*	perennial sowthistle	FACU	
1033	*Sonchus asper*	prickly sowthistle	FACU	
1035	*Sonchus oleraceus*	sowthistle	FACU	
1039	*Spergularia media*	sea spurrey	FAC	326
1050	*Sporobolus anglica*	spartina	OBL	262
1054	*Stellaria alsine*	bog stitchwort	FACW	328
1055	*Stellaria graminifolia*	stitchwort	FAC	327
1105	*Veronica scutellata*	marsh speedwell	FACU	514
1106	*Veronica serpyllifolia*	turf speedwell	FAC	515
1122	*Zantedeschia aethiopica*	arum lily	FAC	66

Table 3 - Key undesirable species of palustrine and estuarine wetlands, with annotations relevant to Otago.

Based on Table 7 in Clarkson BR, Sorrell BK, Reeves, Paula N, Champion PD, Partridge TR, Clarkson BD 2003 (revised 2004): Handbook for Monitoring Wetland Condition. Coordinated Monitoring of New Zealand Wetlands A Ministry for the Environment Sustainable Management Fund Project (5105).

Species	Common Name	Wetland Status
Alnus glutinosa	alder	palustrine
Alternanthera philoxeroides	alligator weed	palustrine (not in Otago)
Carex divisa		estuarine
Carex leporina (= ovalis)	oval sedge	palustrine
Glyceria maxima	reed sweetgrass	palustrine
Iris pseudacorus	yellow flag iris	palustrine
Juncus acutus	sharp rush	estuarine (not in Otago)
Juncus articulatus	jointed rush	palustrine
Juncus bulbosus	bulbous rush	palustrine
Juncus gerardii	saltmarsh rush	estuarine
Juncus squarrosus	heath rush	palustrine
Lycopus europaeus	gypsywort	palustrine
Lythrum salicaria	purple loosestrife	palustrine
Osmunda regalis	royal fern	palustrine (not in Otago)
Paspalum distichum	Mercer grass	palustrine (not in Otago)
Paspalum vaginatum	seashore paspalum	estuarine
Phalaris arundinacea	reed canary grass	palustrine
Salix cinerea	grey willow	palustrine
Salix fragilis	crack willow	palustrine
Schedonorus phoenix (Lolium arundinaceum)	tall fescue	palustrine
Schoenoplectus californicus	Californian club-rush	estuarine (not in Otago)
Spartina alterniflora	American spartina	estuarine
Spartina anglica	spartina	estuarine
Ugni molinae	strawberry myrtle	palustrine
Ulex europaeus	gorse	palustrine
Vaccinium corymbosum	blueberry	palustrine
Zizania latifolia	Manchurian rice grass	palustrine (not in Otago)

Appendix III

ACRONYMS as in Lee & Johnson 2024, for Otago Regional Council

dLWRP draft Land and Water Regional Plan (Otago Regional Council)

DoC Department of Conservation

eDNA Environmental DNA

EH Ecosystem Health (e.g. McGlone et al. 2020)

FMU Freshwater Management Unit

LCDB New Zealand Land Cover Database

MCI Macro-Invertebrate Community Index (Stark et al. 2001)

NEMS National Environmental Monitoring Standards (e.g. Collins Consulting 2022)

NPS-FM 2020 National Policy Statement for Freshwater Management 2020

ORC Otago Regional Council

TICI Taxon-Independent Community Index (e.g.Wilkinson et al. 2024)

WCI Wetlands Condition Index (Clarkson et al. 2003)

WPI Wetland Pressure Index (Clarkson et al. 2003)

WONI Wetlands of National Importance (N.Z.)

Other sources for which no acronym used in report:

National Biodiversity Assessment Framework (e.g. McGlone et al. 2020, re. use by DoC)

New Zealand Threat Classification System (e.g. McGlone et al. 2020, re. use by DoC)