HANDBOOK FOR MONITORING WETLAND CONDITION

Coordinated Monitoring of New Zealand Wetlands
A Ministry for the Environment Sustainable Management Fund Project (5105)

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1. Introduction

Wetlands are among the most important ecosystems on Earth. They improve water quality, control floods, regulate global carbon levels, have significant cultural and recreational values, and provide habitat for plants and animals uniquely adapted to living in the wet conditions. However, since European settlement, New Zealand wetlands have been greatly reduced and only about 10% remain (Ministry for the Environment 1997). As a result, these wetlands support a disproportionately high number of New Zealand's threatened plants and animals.

Recognising these issues, many individuals and organizations have focused on preventing the further loss of wetlands. While this is a necessary and commendable first step, a range of external pressures can lead to a decline in the health or condition of the wetlands that remain. For example, changes in hydrology, water pollution, nutrient enrichment, and invasion by weeds and pests can lead to biodiversity loss and impaired wetland functioning.

Monitoring is important for detecting these negative changes so remedial action can be taken, preferably at the earliest opportunity. Wetland restoration is also on the increase as evidenced by numerous public and private projects, and monitoring is essential for assessing the effectiveness of restoration efforts.

New Zealand is obliged to monitor the health and condition of wetlands as a signatory to two international conventions (Convention on Biological Diversity and the Ramsar Convention on Wetlands). The responsibility for meeting the obligations of these conventions is shared between several central government agencies, in particular the Department of Conservation and the Ministry for the Environment. Local authorities also have a responsibility under the Resource Management Act 1991 (RMA91) to monitor the state of the environment '*to the extent that is appropriate to enable the local authority to effectively carry out its functions under this Act'* s35 2 (a). As one of these functions is to preserve the natural character of wetlands under s6 (a), there is effectively a statutory obligation for local authorities to monitor the state of wetlands.

To assist with these requirements, this handbook[1] describes a set of science-based indicators that have been developed to monitor the condition of New Zealand estuarine and palustrine wetlands. It has been designed for managers, landowners, community groups and anyone else with a need to monitor the condition of wetlands.

The handbook specifically covers:

- The approach and process involved in developing the indicators
- A detailed description of each indicator and how to assign a value and tally scores to analyse the results
- How the indicators can be used to answer a range of monitoring questions
- How the science-based indicators relate to the other objectives and products of the Co-ordinated Monitoring of New Zealand Wetlands Project

[1]Reference: Clarkson B.R., Sorrell B.K., Reeves P.N., Champion P.D., Partridge T.R., Clarkson B.D. 2003: Handbook for monitoring wetland condition (Revised October 2004). Coordinated Monitoring of New Zealand Wetlands. A Ministry for the Environment Sustainable Management Fund Project (5105). doi:10.7931/J2Z60KZ3

2. Coordinated Monitoring of New Zealand Wetlands

The development of wetland condition indicators is part of a wider project to develop tools for consistent monitoring of New Zealand wetlands. The project is linked to the Environmental Performance Indicator Programme being run by the Ministry for the Environment.

Phase 1 of the wetland-monitoring project began in 1998. It involved developing a hierarchical classification system for New Zealand wetlands (Table 1) and a method for monitoring change in wetland extent. The project focused on estuarine (coastal wetlands semi-enclosed by land and dominated by effects of saline water) and palustrine (dominated by shallow freshwater with attached/rooted vegetation) wetlands. Other projects on lacustrine (lakes) and riverine (rivers) ecosystems have also been commissioned by the Ministry for the Environment. The final report from Phase 1 (Ward and Lambie 1999) can be downloaded from the SMF website at: http://www.smf.govt.nz/results/5072_final.pdf

Phase 2 of the project builds on Phase 1 and consists of three main parts:

- Developing science-based indicators for wetland condition, and producing a handbook for managers
- Developing a generic set of matauranga Maori-based indicators for wetland condition and trend
- Producing an illustrated field guide and key to the national wetland classification developed in Phase 1

The matauranga Maori indicators field sheet is appended (Appendix I), and the full report (Harmsworth 2002) is currently available at:
http://www.landcareresearch.co.nz/research/social/maoriindicators.asp

All reports from phase 2 of the Coordinated Monitoring of New Zealand Wetlands project are available via the SMF website (see above; project 5105), or the National Wetland Trust website: http://www.wetlandtrust.org.nz

3. Approach

A workshop was held in November 2000 to identify criteria needed to develop condition indicators that would be practical to wetland managers. Following the workshop, an initial set of indicators was developed and subsequently tested in field trials in 15 wetlands: Northland (Lake Ohia, Lake Taharoa, Maitahi Wetland, Waiparaheka Reserve, Waitangi Forest Wetland); Auckland (Lake Tomarata, Omaha Estuary); Waikato (Whangamarino Wetland); Bay of Plenty (Kaituna Wetland); Wellington (Pauatahanui Estuary); Canterbury (Cockayne Reserve, Travis Swamp); West Coast (Okarito Lagoon); and Southland (Awarua Bog, Waituna Lagoon). The trial sites were selected on the basis of representativeness, existing information, significance, size, threats, and land use pressures. The field trials were carried out in collaboration with wetland managers, iwi, landowners, and other interested parties.

Table 1: SMF Coordinated Monitoring of New Zealand Wetlands classification framework for Palustrine and Estuarine wetlands

Level I **Hydrosystem**	**Level IA** **Sub-System**	**Level II** **Wetland Class**	**Level IIA** **Wetland Form**	**Level III** **Structural Class** [examples]	**Level IV** **Dominant Cover** [examples]
Estuarine ***(Alternating saline and freshwater)***	Intertidal Subtidal Non-tidal Inter-dunal	Saltmarsh Seagrass meadows Algalflat Mudflat Cobbleflat Rocky reef Sandflat	Estuary Lagoon Dune slack	[e.g. herbfield] [e.g. (wire)rushland] [e.g. forest] [e.g. wormfield] [e.g. cocklebed] [e.g. gravelfield] [e.g. musselreef] [e.g. shrubland]	[e.g. Zostera] [e.g. Leptocarpus/Juncus] [e.g. Avicennia] [e.g. Polychaete] [e.g. Austrovenus] [e.g. Diatomfelt] [e.g. Perna] [e.g. Muehlenbeckia]
Palustrine ***(Vegetation emergent over freshwater, not incl. floating plants)***	Permanent Ephemeral	Marsh Swamp Fen Bog Flush Seep	Shore Artificial Slope Channel Flat Basin Pool	[e.g. reedland] [e.g. algalbed] [e.g. macrophyte bed] [e.g. sedgeland] [e.g. cushionfield] [e.g. rushland] [e.g. rockfield]	[e.g. Typha] [e.g. Enteromorpha] [e.g. Ruppia] [e.g. Carex] [e.g. Leptospermum /Cordyline] [e.g. Donatia] [e.g. Schoenus] [e.g. Nostoc] [e.g. Spirogyra]
Basis of discrimination: Hydrological setting, Salinity	Flow Regime	Substrate, pH, Chemistry	Land Form	Biotic Structure	Dominant species

Over the course of the trials a number of improvements were made to the indicators. The resulting indicators were then discussed and evaluated for their practicality and applicability at a workshop in May 2002 with end users. Issues raised at the workshop have been incorporated into the final set of indicators presented in this handbook.

The indicators that have been developed follow the international trend of using soil and vegetation characteristics as the most important indicators of wetland condition (Cowardin et al. 1979, Faulkner et al. 1989, Tiner 1991, 1999), because they:

(i) cover most or all the area of estuarine and palustrine wetlands, and hence can be sampled in most or all locations within these wetlands;

(ii) are not mobile and therefore are permanent features of the landscape;

(iii) integrate environmental stress factors over long time periods.

The wetland condition indicators are (Fig. 1):

- Change in hydrological integrity.
- Change in physicochemical parameters.
- Change in ecosystem intactness.
- Change in browsing, predation and harvesting regimes.
- Change in dominance of native plants.

Indicators of condition based on, or directed specifically at, other groups of aquatic organisms, or standing water chemistry, are widely used in rivers and lakes but are more rarely applied in palustrine and estuarine wetlands. This is partly due to the reasons discussed above, but also reflects the relatively poor understanding of these features in palustrine and estuarine systems in most countries. New Zealand is no exception: there is currently little information available on the algal flora, invertebrate, and fish communities specific for particular wetland classes or in a form that could be used for condition indicators at present. Some guidelines on how these organisms could be used were presented at the first workshop of this project and are available in the workshop report, but in general this is an information gap that needs addressing before higher trophic levels or taxonomically more difficult groups can be applied as indicators.

A numerical scoring system is used to provide a composite index of natural character as a surrogate measure for the condition of native biodiversity in wetland ecosystems (cf. Spencer et al. 1998). The indicators are scored at both a broad wetland-wide scale (Table 2) and a more detailed plot scale (Table 3) to cater for differences in scale and monitoring requirements, and to underpin scores with quantitative scientific data. The plot-based approach is the technique advocated for monitoring USA wetlands by Keddy (2000) and is the foundation for the Protected Natural Areas Programme (PNAP) in New Zealand (Myers et al. 1987). This approach initiates a process in which detailed field reconnaissance (recce), ground-truthing, selection of representative plots and collection of data, are necessary steps facilitating informed assessment and scoring of indicators.

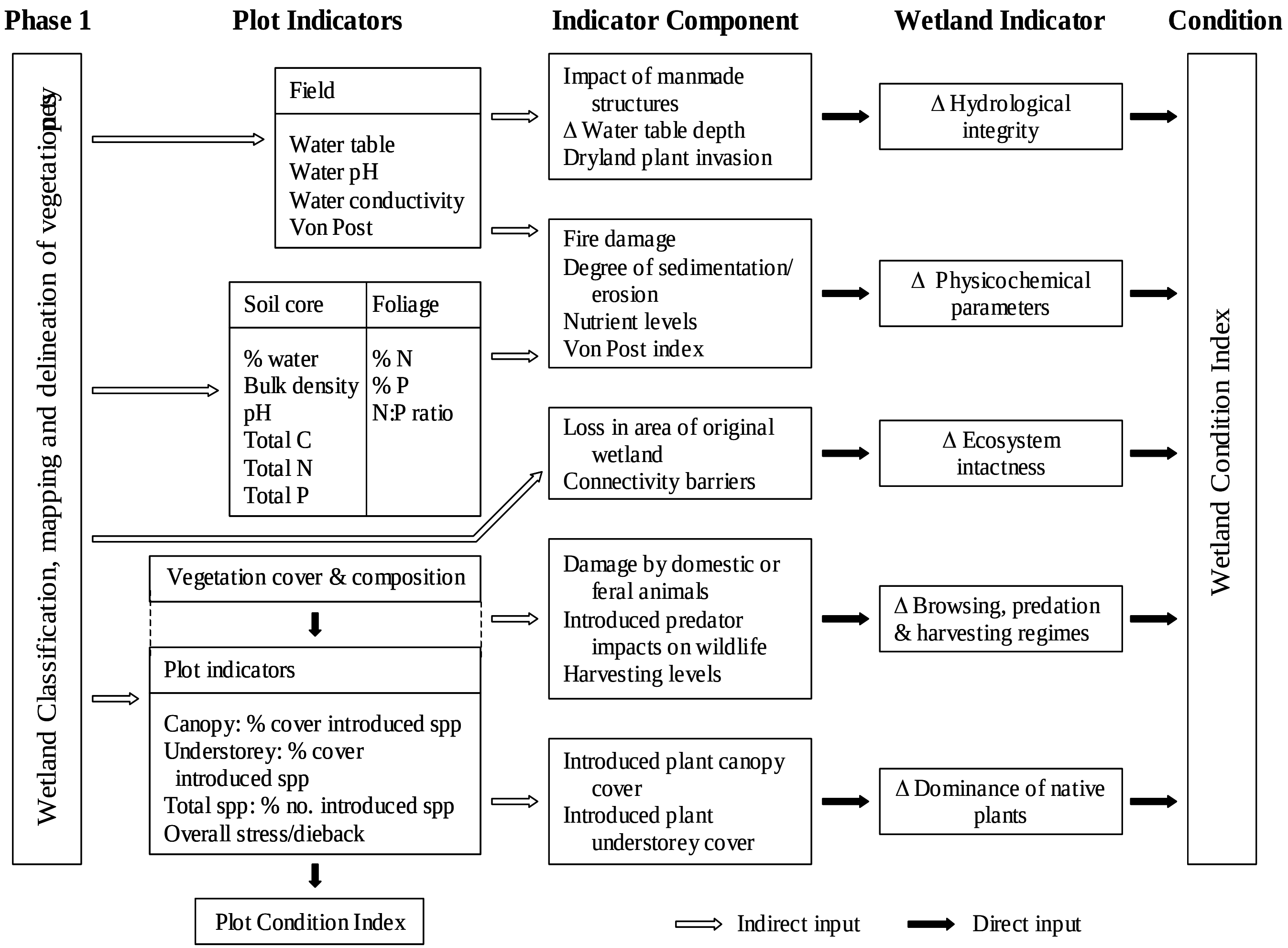


Figure 1: Links between wetland and plot indicators and Phase 1 of the Co-ordinated Monitoring of New Zealand Wetlands project

Table 2: Wetland Record Sheet

Wetland name: **Date:**
Region: **GPS/Grid Ref.:**
Altitude: **No. of plots sampled:**

Classification: I System	**IA Subsystem**	**II Wetland Class**	**IIA Wetland Form**

Field team:

Indicator	**Indicator components**	**Specify and Comment**	**Score 0– 5[1]**	**Mean score**
Change in hydrological integrity	Impact of manmade structures			
	Water table depth			
	Dryland plant invasion			
Change in physico-chemical parameters	Fire damage			
	Degree of sedimentation/erosion			
	Nutrient levels			
	von Post index			
Change in ecosystem intactness	Loss in area of original wetland			
	Connectivity barriers			
Change in browsing, predation and harvesting regimes	Damage by domestic or feral animals			
	Introduced predator impacts on wildlife			
	Harvesting levels			
Change in dominance of native plants	Introduced plant canopy cover			
	Introduced plant understorey cover			
Total wetland condition index /25				

[1]Assign degree of modification thus: 5=v. low/ none, 4=low, 3=medium, 2=high, 1=v. high, 0=extreme

Main vegetation types:

Native fauna:

Other comments:

Pressure	**Rating[2]**	**Specify and Comment**
Modifications to catchment hydrology		
Water quality within the catchment		
Animal access		
Key undesirable species		
% catchment in introduced vegetation		
Other pressures		
Total wetland pressure index /30		

[2]Assign pressure scores as follows: 5=very high, 4=high, 3=medium, 2=low, 1=very low, 0=none

Table 3: Wetland Plot Sheet

Wetland name: **Date:** **Plot no:**
Plot size (2m x 2m default)**:** **Altitude:** **GPS/GR:**
Field leader: **Structure:** **Composition:**

Canopy (bird's eye view)			**Subcanopy**			**Groundcover**		
Species[1] (or Substrate)	**%**	**H**	**Species**	**%**	**H**	**Species**	**%**	**H**

[1] % = % cover: total canopy % cover = 100%; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type:

Comments:

Indicator (use plot data only)	**%**	**Score 0–5**[2]	**Specify & Comment**
Canopy: % cover introduced species			
Understorey: % cover introduced spp[3]			
Total species: % number introduced spp			
Total species: overall stress/dieback	NA		
Total plot condition index /20	NA		

[2]5=0%: none, 4=1–24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; very high
[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm		Water conductivity uS (if present)	
Water pH (if present)		von Post peat decomposition index	

Soil core laboratory analysis (2 soil core subsamples)**:**

Water content % dry weight		Total C %	
Bulk Density T/m^3		Total N %	
pH		Total P mg/kg	
Conductivity uS			

Foliage laboratory analysis (leaf/culm sample of dominant canopy species):

Species		%N		%P	

The links between the wetland and plot information, and the wetland classification from Phase 1 of the project, are summarised in Figure 1. The first step involves a Phase 1 wetland classification and map, delineating the vegetation types or habitats present. This provides information on the number and areal extent of vegetation types at an appropriate scale. Permanent plots, selected as being representative of the vegetation types, are established, with a minimum of one plot per major vegetation type. These plots yield quantitative data, which are used to assess and score the condition of the vegetation within the plot, and provide a baseline to detect future changes in physical, chemical, and biological parameters. The wetland scale indicator components are assessed and scored on a 0–5 scale following field reconnaissance of the whole wetland, consideration of historical and other information, and interpretation of the plot data. A sub-index for each wetland indicator is then calculated by averaging the scores of the appropriate indicator components. If a condition index for the whole wetland is desired, the wetland indicator sub-indices are summed to give a total out of 25.

4. Selection of Wetlands for Monitoring

The selection of wetlands for monitoring will depend on the specific requirements of the monitoring project. In some cases, the project may consist of all wetlands within a pre-determined area. In other cases, particularly at region or subregion levels, a sub-sample of wetlands may be more appropriate. If a sub-sample is used, the wetlands selected for monitoring should be representative examples of the natural ecological diversity of wetland ecosystems in the region. This can be based on frameworks or filters such as land environments (domains), ecological regions and districts, bioclimatic zones, hydro-ecological classes, land systems, etc (see Myers et al. 1987). Selection of representative wetlands should reflect the former wetland type and extent, altitudinal and geographical range, and the vegetation structure and composition that existed within the region. This will ensure both rare and common wetlands and wetland habitats are encompassed in the monitoring programme. Maps (particularly GIS-based maps) of both former and present day wetland extent, class, and where possible, vegetation type, following the Phase 1 wetlands classification and mapping system, are pre-requisites for the robust selection of representative wetlands.

Sometimes, more intensive monitoring may be required in specific wetlands. For example, monitoring might be conducted in a wetland adjacent to a proposed development to assess on-going effects of the development. Other specific projects include monitoring threatened species populations, monitoring effects of chemical spills, and monitoring rates and effects of weed invasion. The basic monitoring regime can be extended and modified by increasing the number of permanent plots, sampling across gradients of interest, and adding further components as outlined in Section 6.1.

Modifications to suit specific monitoring needs can be added to electronic versions of the basic wetland and plot record sheets, which are available by emailing wetlanddatabase@landcareresearch.co.nz.

5. Wetland Record Sheet

5.1 Features

The Wetland Record Sheet (Table 2) has three main components:

- The first section provides the link to Phase 1 with a classification at the System, Subsystem, Class and Form levels (summarised in Table 1)
- The second section is for scoring condition indicators
- The third section is for scoring of pressures likely to affect future condition

Fields are also provided to record location details, by whom the assessment was made, the main vegetation types (using the Atkinson (1985) system: Appendix V), native fauna, and other comments about the site.

5.2 Indicators

Five semi-independent indicators of current state (condition) have evolved during trials in different wetland types throughout New Zealand. They are based on major threats and stress factors known to damage wetlands. Each indicator comprises a number of components, scored using a semi-quantitative technique that enables assessment of the degree of modification that has occurred. Indicator component scores are averaged to produce a sub-index indicator score, which is totalled to provide an overall index that represents condition of the wetland.

Each indicator component is scored on a scale from 0 to 5, with 5 representing the unmodified or best condition and 0 representing the most degraded condition. A 'Specify and Comment' column provides information on the reason a particular score has been given so it can be recalled at a later date. This is essential if the scoring system is to be used to monitor change in condition over time, which is its main function. The scores are based on observations made and data collected during site visits and from knowledge/data about the site already available.

There is inevitably some overlap and interdependence of the indicator components – most activities that damage wetlands will affect more than one indicator. This is not necessarily a disadvantage for the scoring system, as it emphasises the issues that are the most serious threats to wetlands.

The indicators are scored for the wetland as a whole. They are:

- Change in hydrological integrity
- Change in physicochemical parameters
- Change in ecosystem intactness
- Change in browsing, predation and harvesting regimes
- Change in dominance of native plants

The changes are estimated against estimated baselines of regimes that would have existed in the absence of human-induced modification (e.g., before European settlement). Indicators and associated components, together with justification for selection and visual clues, are summarised in Table 4. Guidelines for allocating scores on the 0–5 scale are given in Table 5.

Change in hydrological integrity

Hydrology is probably the single most important determinant of the establishment and maintenance of specific types of wetlands and wetland processes (Mitsch and Gosselink 2000). Although several hydrologic parameters may be measured (e.g., water inflows, outflows, groundwater input, physical conditions), the water budget of a palustrine wetland may be developed relatively simply and cheaply from continuous measurements of water levels. With records of water level, all the following hydrologic parameters can be determined: hydroperiod, frequency of flooding, duration of flooding, and water depth.

Relatively simple instrumentation can be used to provide a clear picture of water level changes in wetlands: staff gauges in deeper sites with standing water; and permanent dipwells, piezometers or water level recorders for water levels below the surface. Electronic water level recorders are now available that can be logged automatically and reduce costs, allowing an increased sampling frequency and fewer site visits. In sites where hydrological change is thought to be a significant problem and more detailed information is desired, additional techniques may include rain gauges, evaporation pans for measuring evapotranspiration, V-notch weirs and tipping buckets for inflows and outflows, and tensiometers that describe the degree of saturation of the soil above the water table (Mitsch and Gosselink 2000).

Unlike many of the other parameters used in scoring condition, hydrology is difficult to score meaningfully from single site visits. Therefore additional monitoring of, or historical information on hydrological regime would provide an improved understanding of change. For most monitoring programmes, measurements of water-table depth integrated over time will provide a good indication of whether drainage or flooding are modifying hydrological patterns. Lowered water tables may also be caused by unusual climatic conditions, such as drought. Hence, long-term water table data are usually required to separate out natural fluctuations caused by climatic events, from unnatural fluctuations, flooding or declines resulting from human modifications.

If these data are not available, the presence of manmade structures that influence hydroperiod can be used as simple indicators of changes to hydrological integrity. Look for the kinds of human-induced changes in hydrological regime that are likely to damage wetlands. Most wetland ecosystems are adapted to and are likely to tolerate short-term disruptions in their water regime, depending on the species composition. For example, the natural closing of the bar of a coastal lagoon for a few months, and the increase in water level that results, is unlikely to cause a change in species composition or long-term nutrient storage.

Table 4: Justification of the indicators used and their relationship to wetland function

Indicator	**Functions affected**	**Indicator Components**	**Justification**	**Visual clues**
Change in hydrological integrity	Groundwater recharge/discharge; medium for biogeochemical processes; habitat for biota; recreation	H1: Impact of man-made structures that alter hydrological regime	Water arguably paramount wetland determinant (Mitsch & Gosselink 2000). Structures alter (mostly decrease) water inflows/outflows.	Number/ size/ depth/ effectiveness/ coverage of man-made structures (drains, stopbanks, tide gates, etc.) within wetland and in catchment. Extent of wetland affected by structures. Includes permanent flooding changes.
		H2: Change in water table depth	Drainage causes lowered water tables. Water tables surrogate for water budget in palustrine wetlands.	Water table decline (need long-term plot data), loss/decline of species requiring high water table e.g., aquatic and semi-aquatic species such as bladderwort.
		H3: Dryland plant invasion	Dryland species, e.g., broom, gorse, kanuka indicate a drop in water table.	As above, but presence/increase of dryland species/vegetation
Change in physico-chemical parameters	Vegetation growth; nutrient storage; water quality	P1: Fire damage	Fire destroys vegetation/ fauna. Recovery is usually relatively quick. Temporarily increases nutrients (pre-fire levels return after *c.*2 years).	Recent fires evident from loss of late successional vegetation, sparse vegetation cover, charred trunks of woody species, visible ash deposits. Fires >2 years ago discernible from ash/charcoal layers in soil cores, absence of fire-sensitive species from vegetation (e.g., *Carex secta* in swamps, *Empodisma*, *Sporadanthus* in bogs)
		P2: Degree of sedimentation/ erosion	Increased levels reduce water quality by, e.g., reducing light penetration.	Recent earthworks or freshly dug drains in the catchment. Abrupt change in soil colour. Plants partially buried by sediment. Suspended sediments.
		P3: Nutrient levels	Increased levels cause changes to vegetation/ faunal habitat. Salinity changes affect biota.	Changes (mainly increases) in soil/water N, P & pH, foliage N:P ratio (from plot data), loss/decline of species adapted to oligotrophic conditions (especially slow-growing stress tolerant plants), change in phytoplankton composition, e.g., from diatoms to large filamentous Cyanobacteria
		P4: von Post index Peat bogs only	Peat decomposition levels reflect peat-forming processes (health). Decomposition increases nutrients.	Squeeze technique – decomposition low if only water escapes through fingers, high if peat escapes. Loss of peat forming species, e.g., *Empodisma*, sphagnum. (Use plot data and recce).

Indicator	**Functions affected**	**Indicator Components**	**Justification**	**Visual clues**
Change in ecosystem intactness	Fauna & flora diversity/ abundance/ breeding/migration	E1: Loss in area of original wetland	Area strongly related to population size and often to species diversity, due to smaller fragments having lower habitat diversity, greater edge effects, failure to provide minimum resources, e.g., nesting area.	Usually monitored over time in databases by mapping exercises, often from aerial photography or historical information. Visual evidence at individual wetlands in the absence of any existing information can be observed in soil cores, presence of remnants of wetland vegetation in old wetland areas, topography or obvious reclamation.
		E2: Connectivity barriers	Lack of upstream or downstream connections prevents migration, especially of fauna, but also seed dispersal, destroys natural salinity gradients and nutrient supply.	Presence of tide gates, stop banks, weirs isolating system from riverine connections to other wetlands. Ring drains and box culverts around margin isolate wetland from catchment groundwater. Loss of riparian vegetation and buffer vegetation connecting wetlands to native forests, lakes and rivers.
Change in browsing, predation and harvesting regimes	Vegetation composition and structure; fauna diversity/ abundance/ breeding	B1: Damage by domestic/feral animals.	Damages soil structure and chemistry, destabilises soil, increases turbidity, damages native vegetation and encourages weed invasion and movement of mammalian predators. Loss of habitat.	Browse damage to foliage, branchlets; soft, herbaceous, palatable plant species absent or greatly reduced in number and stature. Animal tracks visible in wetland. Damage to bark, e.g., biting and scratching. Disturbance to substrate, e.g., deer wallows, pig rooting, pugging of soil. (Use plot data and recce). Adequacy and extent of fencing.
		B2: Introduced predator impacts on wildlife	Reduces wildlife species diversity and abundance, and recreational values.	Direct evidence from datasets (e.g., 5-minute bird counts, standard native fish trapping methods, or predator trapping). Indirect evidence from predator tracks, scat counts. Presence of sensitive species such as fernbird, bittern, banded rail would indicate low predator impacts.
		B3: Harvesting of biota	Reduces species diversity and abundance. Harvesting of dominant plants destroys habitat value, can also lead to erosion and nutrient exports.	Recent vegetation harvesting readily observed; longer-term effects may be evident in absence of key species from communities where they typically occur.

Indicator	Functions affected	Indicator Components	Justification	Visual clues
Change in dominance of native plants	Habitat for fauna; vegetation composition and structure; recreation; natural character	D1: Introduced plant canopy cover	Introduced plants can change wetland structure and function; may have poorer habitat value for native fauna, increase in sedimentation, drying and create monocultures (e.g., willows, tall fescue).	From data: cover of introduced plants in plots and, especially, increase over time. Extent of introduced plant invasion determined from aerial photos or high vantage points. Use plot cover data (e.g., from multiple plots along invasion gradients) for quantitatively monitoring change over time.
		D2: Introduced plant understorey cover	Reflects degree of degradation or restorability of wetland, e.g., introduced plant canopy may have native understorey. Introduced plant dominated understorey indicates high modification.	Determined from recce and plot data. Canopy composition and historical information will give clues to understorey composition, e.g., long-established willow forest will likely have low native understorey.

Table 5: Guidelines for scoring of indicator components

Indicator and components	Score and degree of modification					
	5	**4**	**3**	**2**	**1**	**0**
	None/very low	**Low**	**Moderate**	**High**	**Very high**	**Extreme**
Δ Hydrological integrity H1: Impact of manmade structures	None or not impacting on wetland.	Affect less than 25% of the wetland.	Affect 25–49% of the wetland.	Affect 50–75% of the wetland.	Dominate wetland (>75%)	Totally dominated or affected by man-made structures.
H2: Δ Water table depth	No detectable changes.	Abnormally lowered (or raised) only occasionally and temporarily	Noticeably lower for short periods during dry spells. Average water table shows small but definite decline over time.	Lowered for long periods during dry spells. Average water table in wetland has noticeably declined over time.	Very low for most of year, not recharged fully by high rainfall events. Average water table much lower than previously.	Unable to be easily measured throughout season. Now a ‘dryland’ Or artificially totally flooded.
H3: Dryland plant invasion	No/ virtually no dryland plants in wetland.	<25% of wetland has dryland plant species present	25–49% of wetland has dryland plant species present.	50–75% of wetland has dryland plant species present.	>75% of wetland has dryland plant species present.	All species (100%) in community are dryland species
Δ Physicochemical parameters P1: Fire damage	No evidence of fire damage.	Recent fires (<2 years) removed vegetation in <25% of wetland; Or vegetation virtually recovered from older fires.	Recent fires (<2 yr) affected 25–49% of wetland; Or veg in 50–75% wetland still recovering from older fires.	Recent fires (<2 yr) affected 50–75% of wetland; Or veg in >75% wetland still recovering from older fires.	Recent fires (<2 yr) affected >75% of wetland. Or fire sensitive species now extinct.	Above ground vegetation completely destroyed (immediately post-fire).
P2: Degree of sedimentation/ erosion	None: high water clarity (<40 NTU), no visible sediment, stable banks and soil.	Water clarity 41–80 NTU; Or visible sediment deposits affect <25% of wetland; Or some minor spot erosion visible.	Water clarity 81–120 NTU; Or visible sediment deposits affect 25–49% of wetland; Or erosion spots linked and causing minor structural damage.	Water clarity 121–160 NTU; Or visible sediment deposits affect 50–75% of wetland; Or widespread erosion or scouring over greater than 50% of area.	Water clarity >160 NTU; Or visible sediment deposits affect >75% of wetland; Or widespread erosion causes severe damage throughout.	All wetland character lost due to prolonged extreme turbidity, almost total infilling by sediment, or unchecked erosion and scouring.

Indicator and components	Score and degree of modification					
	5	**4**	**3**	**2**	**1**	**0**
	None/very low	**Low**	**Moderate**	**High**	**Very high**	**Extreme**
P3: Nutrient levels	No evidence of eutrophication.	Localised (<25%) or infrequent signs of algal blooms or changes in nutrient concentrations or vegetation composition.	25–49% of area shows algal blooms, increased nutrients or vegetation change to high-nutrient species.	50–75% of area shows algal blooms, increased nutrients or vegetation change to high-nutrient species.	Eutrophication has shifted >75% of system to almost continuous algal blooms or monospecific stands of high-nutrient plants.	All wetland character lost due to eutrophication: now just a pond or dryland with no higher wetland plants present.
P4: von Post index Relevant to peat bogs only	1 undecomposed; plant structure unaltered, yields clear colourless water.	2–3; plant structure distinct, yields clear, yellow or brown water.	4–5; plant structure becoming indistinct. Yields turbid brown water, some peat may escape between fingers, residue mushy.	6–7; plant structure indistinct, about half the peat escapes between fingers, residue strongly mushy.	8–9; plant structure very indistinct, two-thirds to almost all peat escapes between fingers.	10 completely decomposed; plant structure unrecognisable, all peat escapes between fingers.
Δ Ecosystem intactness E1: Loss in area of original wetland	No loss: original wetland area essentially intact.	<25% of original area lost.	25–49% of original area lost.	50–75% of original area lost.	>75% of original area lost, remnants still retain some original character.	Wetland lost, or almost lost but remnants completely modified.
E2: Connectivity barriers	None: All natural upstream and downstream connections retained.	<25% of upstream or downstream connection lost.	25–49% of upstream or downstream connection lost.	50–75% of upstream or downstream connection lost.	>75% of connection lost with some minor links remaining.	Isolated: all former connections to other water bodies lost.
Δ Browsing, predation & harvesting regimes B1: Damage by domestic or feral animals	No domestic animal or feral animal browsing or trampling damage.	<25% of wetland showing light-medium damage; Or very light or localised browsing throughout wetland.	25–49% of wetland showing medium-heavy browsing and/or trampling damage.	50–75% of wetland medium-heavily browsed and/or trampled.	>75% of wetland heavily browsed and/or trampled.	All wetland character lost due to severity of browsing and trampling activity.

Indicator and components	**Score and degree of modification**					
	5	**4**	**3**	**2**	**1**	**0**
	None/very low	**Low**	**Moderate**	**High**	**Very high**	**Extreme**
B2: Introduced predator impacts on wildlife	No/virtually no predator access or impact; Or wetland & catchment under long term effective predator control.	Low levels of predators – susceptible wildlife spp still present Or pulsed predator control. Low predator reinvasion from catchment.	Medium predator impact, decline in numbers of some wildlife species. Or control very intermittent /or of not all predators. Medium reinvasion from catchment.	High declines in populations and/or loss of 1 or 2 wildlife species. Or no or ineffective predator control. High reinvasion from catchment.	Severe declines in wildlife population and species number. Or no predator control. Very high reinvasion from catchment Predators/signs visible.	Extreme: most native wildlife species extinct in wetland. Predators/signs highly visible.
B3: Harvesting levels	No harvesting (plants, birds, fish or other components) activity in wetland.	<25% of wetland with medium-heavy harvesting damage; Or light damage throughout wetland Or virtually recovered from earlier harvesting.	25–49% of wetland affected by active harvesting; Or 50–75% of wetland recovering from earlier harvesting.	50–75% of wetland affected by active harvesting; Or >75% of wetland recovering from earlier harvesting.	Active harvesting affecting >75% of wetland.	All wetland character lost due to harvesting activity.
Δ **Dominance of native plants** D1: Introduced plant canopy cover	No introduced plants in canopy i.e., all plants are native.	<25% canopy cover of introduced plants.	25–49% canopy cover of introduced plants.	50–75% canopy cover of introduced plants.	>75% canopy cover of introduced plants.	All canopy plants are introduced.
D2: Introduced plant understorey cover	No/ virtually no (<1%) plants in understorey are introduced.	<25% cover of introduced plants in understorey.	25–49% cover of introduced plants in understorey.	50–75% cover of introduced plants in understorey.	>75% cover of introduced plants in understorey.	All/virtually all (>99%) plants in understorey are introduced.

The presence of drains and other artificial structures within a wetland are a good indication that hydrological modification (mainly water removal) has occurred. Conversely, drains or other structures in the catchment may divert excess water into wetlands, increasing flooding or flood peaks, e.g., diversion of stormwater into urban wetlands. Further consideration of the importance of changes in catchment hydrology as a pressure indicator is given below in section 4.3

Other hydrological disturbances include blockage/reduction of natural flooding or tidal regimes, e.g., by stop banks. In estuarine systems stop banks may also block saline inputs, thus changing saline/freshwater balance. Salinity gradients in unmodified coastal wetlands sustain a gradual shift in vegetation composition from freshwater to salt-tolerant species. Stopbanks, tide gates and other such barriers result in abrupt shifts from freshwater to estuarine communities, often particularly affecting upper salt marsh communities, which may be lost entirely or heavily invaded by weeds such as tall fescue. Native fish species are particularly sensitive to disturbances of salinity gradients, as spawning is often keyed to the position of the freshwater-saltwater interface relative to tidal cycles.

Reduction of water levels/frequency of flooding in wetlands affects soil biogeochemistry by increasing oxygen penetration and hence decomposition and nutrient release. In peat soils this can lead to increased peat oxidation and degradation over time, and in all soils a more aerobic soil environment facilitates invasions of dryland plants, including many weeds, into wetlands.

Changes in plant community composition can be used as an inexpensive indicator of hydrological disturbances such as drainage and flooding (Wilcox 1995). The presence of a high proportion of dryland species in a wetland is a good indicator of a reduced water regime (Indicator component H3). Dryland plant species invading wetlands can be very useful indicators of drainage, because they integrate the hydrological regime over long time periods, and therefore monitoring their spread is much less labour-intensive and less expensive than direct hydrological monitoring. Their increased presence in wetlands is a rapid, immediate alert to possible effects of drainage. The distinction between a ‘dryland’ and ‘wetland’ plant is a standard indicator in the United States for delineating boundaries in wetland inventories and for regulatory purposes (Tiner 1991). Wetland plants, or *hydrophytes*, are any plants adapted to living in wet conditions. A more specific definition is “any macrophyte (large plant) that grows in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content” (U.S. Army Corps of Engineers 1987). These hydrophytes are distinguished from other plants by specific morphological and physiological adaptations that allow their roots to tolerate and grow in these oxygen-deficient conditions (Sorrell et al. 2000).

It is clear from these definitions that the number of dryland plant species in our flora is vastly greater than the number of wetland species. Common dryland species encountered in wetlands where water regime has declined include the indigenous kanuka (*Kunzea ericoides*), mahoe (*Melicytus ramiflorus*), koromiko (*Hebe stricta*), matagouri (*Discaria toumatou*), tree ferns (*Cyathea* and *Dicksonia* spp.) and a range of other fern species, hard tussock (*Festuca novae-zelandiae*), along with many alien species including gorse (*Ulex europaeus*), broom (*Cytisus scoparius*), privet (*Ligustrum* spp.), elder (*Sambucus nigra*), sweet brier (*Rosa rubiginosa*), browntop

(*Agrostis capillaris*), sweet vernal (*Anthoxanthum odoratum*), fireweeds (*Senecio* spp.), hawksbeard (*Crepis capillaris*) and white clover (*Trifolium repens*). This list is by no means exhaustive and the easiest way to determine non-wetland species is to have a reasonable familiarity with the wetland species that should be present, and to recognise interlopers when they appear. *Wetland Plants in New Zealand* (Johnson and Brooke 1998) provides a comprehensive range of the wetland species found in this country. Remote sensing techniques may help to reduce further the cost of using vegetation as an indicator of hydrological disturbance (Wilcox 1995).

Increases in water depth may cause stress to wetland vegetation because most species need to maintain aerial shoot biomass for their photosynthetic activity, and often cannot survive several days of complete immersion. Their stress response here is to shift their growth towards producing fewer but taller shoots to compensate (Sorrell et al. 2002), but if the water level fluctuates rapidly they may be unable to synchronise growth with water regime. Rapid fluctuations, e.g., those associated with some hydroelectric power operations or irrigation activities, can have very immediate visible effects such as the collapse of shoots of tall emergent plants (e.g., club rush, *Schoenoplectus tabernaemontani*; tall spike rush, *Eleocharis sphacelata*). Species like this can be lost where rapid fluctuations occur and be replaced by species more tolerant of fluctuations, often introduced plants such as *Glyceria fluitans*. Seed germination and seedling survival and establishment are particularly sensitive to wetting and drying cycles, and disturbances to natural establishment patterns are also a frequent problem resulting from rapid fluctuations.

Change in physicochemical parameters

The physicochemical parameters addressed under this indicator heading (sedimentation, nutrient enrichment and fire) are those most commonly affecting New Zealand wetlands on a wetland-wide scale.

Runoff of suspended sediments into wetlands (i) can cause direct smothering of desirable vegetation in shallow wetlands; and (ii) reduces light penetration in standing water. In both cases, sedimentation is usually associated with increased loads of organic matter that increase soil and water respiration, causing the habitat to become more anaerobic and often resulting in vegetation decline and fish kills.

Sediment input may be accompanied by nutrient enrichment, because most anthropogenic sediments in New Zealand have an associated nutrient load. Nutrient enrichment may also occur in groundwater loading and surface run-off. Because palustrine and estuarine wetlands are usually shallow and semi-enclosed, and usually lie in lowland agricultural catchments, they are areas where nutrients can accumulate. Nitrogen and phosphorus additions interact in complex ways to change the nature of nutrient limitation, shifting plant species composition, relative dominance, and productivity. The effect may be a shift from a species-poor vegetation type adapted to low nutrients as in a raised bog, to a more diverse mixture of native and/or introduced species better adapted to the increased fertility. Extremely high additions of nitrogen and phosphorus may cause a shift from a diverse community of short-statured, relatively slow growing plants (as in a swamp) to a less diverse community of productive, tall-growing species, and increased primary and secondary productivity in standing water. Increased productivity and biomass is usually followed by increased rates of decay and community respiration, leading to anaerobic conditions with deleterious effects on invertebrate, fish and bird populations as discussed above. Because eutrophication is such an important issue for our wetlands, methods for detecting it from soil and vegetation parameters are included at the plot scale. On a broader scale, it can be inferred indirectly from vegetation species changes, and where standing water is present, from changes in planktonic community composition.

Additional stress factors may also occur, such as other types of pollution that are less common in New Zealand but may be important in certain locations. For example, acid drainage from mining activities can be detected from lowered pH, or increased iron and sulphur concentrations. Heavy metals can have particularly severe ecological effects, and metal accumulation due to wastewater discharges have been documented in natural wetlands in New Zealand (Chagué-Goff and Rosen 2001).

Fires may occur naturally, but most often in New Zealand they are human-induced, either as a result of vandalism or a belief that fires somehow ‘improve’ the system. Pakihi and other bog vegetation are particularly prone to this type of burning, especially when fuel buildup is high or the vegetation has a high proportion of flammable species such as *Dracophyllum*. In swamps, species such as *Typha* that produce large amounts of dead standing biomass during the season are also susceptible to burning. Intensive, ‘hot’ fires not only destroy aboveground vegetation directly, but also can burn deep into the peat, destroying underground plant rhizomes that usually survive less intensive ‘cool’ fires. Fires increase nutrient levels in peatlands temporarily – usually returning to pre-fire levels within two years (Wilbur and Christenson 1983). They can also degrade peat and increase nitrogen limitation as organic nitrogen is volatilised during burning. Wildlife values are also usually lowered by fire, which removes material and shelter for bird nesting. The increases in sediment runoff and changes in invertebrate communities in standing water that result from fire also have indirect effects on both native fish and salmonid populations.

For peat bog systems, the von Post index (Clymo 1983) is a simple and useful indicator of peat decomposition or health. Intact, peat-accumulating bogs have low peat decomposition, i.e., the dead plant structure forming the peat matrix is distinct and the associated water is virtually colourless. Decomposition increases when peat-forming species have been removed, e.g., by fire or drainage, or there have been detrimental changes in hydrological regime, such as lowered river levels (Shearer and Clarkson 1998). Highly decomposed or degraded peat is characterised by mushy, structureless ‘porridge’ that oozes through fingers when wet peat is squeezed in the hand.

Change in ecosystem intactness

An intact, large wetland ecosystem is likely to maintain its long-term viability because functional processes enable the system to resist direct and indirect human effects. An intact wetland will also have full ecosystem links for all constituent species, e.g., wildlife corridors and links to the sea for diadromus fish species. Ecosystems that have been greatly reduced from their former extent will have modified disturbance-recovery cycles and some habitats may be below minimum area thresholds to buffer against environmental disturbance. Small, fragmented populations are vulnerable to extinction, especially through habitat loss and disruption of life support systems. The shape and size of remaining wetland areas will affect the ultimate success of maintaining viable communities, with small, non-compact (high perimeter:area ratio) fragments having lower natural diversity and greater edge effects.

The original extent of wetlands and wetland classes can be assessed and mapped using a combination of historical information, soil maps, macro- and micro-fossil data, aerial photographs, and existing wetland data. This provides a baseline for assessing loss in area of a wetland as well as its representativeness of the range of former communities (including structure and species composition) in proportion to their former extent.

This indicator does not include wetlands that have changed in species composition but not area, e.g., willow treeland replacing a former C*arex* sedgeland. Replacement of native species by introduced species will be scored under the Change in dominance of native plants indicator. Induced wetlands dominated by native vegetation but which are different from the original vegetation, e.g., cabbage trees replacing kahikatea forest, should be indicated in the "comments" sections of the Wetland Record Sheet.

The fragmentation of a wetland into isolated islands in a 'sea' of modified habitats (e.g., most of the former wetland now drained and converted to pasture) will also detrimentally affect aerial or overland dispersal of species with low dispersal capability, e.g., some birds, insects, spiders, and plants. Barriers to aquatic dispersal include blockage or removal of upstream and downstream connections by weirs, ring drains, and box culverts, which prevent migration of fauna, especially fish. In estuarine systems, tide gates, stop banks, causeways, and artificial opening of lagoon mouths may alter salinity/freshwater gradients, which may affect species with specific habitat salinity requirements.

Change in browsing, predation and harvesting regimes

In pre-human time predation regimes were very different from the present day. Birds, bats, and insects consumed shoots, flowers, fruits, seeds, and roots, and predators such as birds, sea mammals, fish, and invertebrates preyed on smaller animals. The balance was upset with the arrival of man and associated introduced browsing and predatory animals. Introduced animals can cause damage that results in changes in community structure, and species composition and abundance, which facilitate invasion of weeds and pests, and loss of intolerant species.

Domestic stock, because of their large size, can cause severe damage to soil and plants from trampling and browsing. However, they are relatively easy to exclude, usually by securely fencing the perimeter of a wetland. Visual clues to the presence of domestic stock are stock or dung in the wetland, pugging, trampled or heavily grazed vegetation, and paddocks adjoining wetlands with no fences or poorly maintained fences between them.

Feral animals damage both flora (by browsing, substrate disturbance) and fauna (by predation and displacement). They are less visible than domestic stock, usually being small, wary and/or nocturnal, and are much harder to control or eradicate. The predator component of this indicator is relatively difficult to assess, as accurate information on predator and prey numbers usually requires intensive data collection.

However, the degree of modification can be assessed from visible clues such as levels of predator scats, bird counts, historical information, frequency, extent and intensity of predator control programmes, and potential degree of invasion from surrounding catchment.

Change in dominance of native plants

This indicator is assessed by determining the degree to which native plants have been displaced by introduced plants. Introduced plants can modify wetland function and structure and are one of the major threats to wetland condition throughout New Zealand. Palustrine wetlands of relatively high fertility, e.g., swamps and fens, are particularly vulnerable to invasion by fast-growing deciduous trees such as willow because they are exploiting an ‘empty niche’. New Zealand does not have an ecological equivalent native tree species in these wetlands, which are characterised by sedges, shrubs and other low-growing species. Grey willow is particularly troublesome in wetlands because it is readily spread by abundant wind-dispersed seed, and can grow in high and relatively low nutrient conditions, e.g., in swamps, fens and margins of young peat bogs. Dominance by introduced trees will alter light levels reaching understorey layers and, over time, may cause displacement of high light-requiring native species. In addition, deciduous trees cause pulses in nutrients in autumn associated with massive leaf fall. As a consequence, native flora and fauna adapted to the native evergreen system, may also decline in abundance and/or become extinct.

Wetlands recently invaded by introduced plants may have a non-native canopy overtopping the former, relatively intact native plant community. However, over time, the understorey usually also becomes dominated by introduced species that are better adapted to the changed light, nutrient and other regimes. Comparison of the extent of introduced plant cover in both the canopy and understorey layers enables assessment of the degree of degradation of the wetland, and is also a useful tool in assessing how much effort would be required for its restoration.

5.3 Wetland Pressures

The pressure section of the wetland record sheet (Table 2) is a separate score in which external factors that threaten future condition are identified. The pressures are:

- Modifications to catchment hydrology
- Water quality within the catchment
- Animal access
- Key undesirable species
- % catchment in introduced vegetation
- Other pressures

Table 6 provides guidelines for scoring wetland pressures using a scale of 0–5. Note that a high value indicates the greatest pressure and therefore wetlands that score highly are most under risk of being degraded.

Table 6: Guideline for scoring pressures

Pressure	Score and degree of modification					
	None/very low (0)	Low (1)	Moderate (2)	High (3)	Very high (4)	Extreme (5)
Modifications to catchment hydrology	No hydrological modifications to the catchment.	<25% of catchment has been subject to hydrological modification. NB urban (impervious surface) catchment would score higher than grass.	25–49% of the catchment has been subject to hydrological modification.	50–75% of the catchment has been subject to hydrological modification.	Over 75% of the catchment has been subject to hydrological modification.	The entire catchment has been subject to hydrological modification.
Water quality with-in the catchment. (Using water quality index, e.g., SQMCI by Stark, 1998)	Very high water quality.	Good water quality.	Possible mild pollution.	Probable moderate pollution.	Probable severe pollution.	Severe pollution.
Animal access	No animal access (either no pest animals in the catchment or wetland surrounded by predator proof fence).	High impediment to animal access, low edge:area ratio, intensive trapping /eradication programs within catchment, mostly surrounded by native ecosystems.	Moderate impediment to animal access, moderate edge to area ratio, control of some key undesirable species, some of the catchment in one modified land use.	Low impediment to animal access, moderate edge to area ratio, control of some key undesirable species, several different land-uses within catchment.	Low impediment to animal access, high edge to area ratio, surrounded by a mix of intensive land uses, no control programmes in the catchment.	No impediment to animal access, high edge to area ratio, surrounded by a mix of intensive land uses, no control programmes in the catchment.
Key undesirable species (found in region that could invade wetland type being monitored)	No key undesirable species found within the catchment	Less than 25% of key undesirable species are found within the catchment.	Between 25–49% of key undesirable species are found within the catchment.	Between 50–74% of key undesirable species are found within the catchment.	Over 75% of key undesirable species are found within the catchment.	All key undesirable species are found within 100m of the wetland.
% Catchment in introduced vegetation	None of the catchment in introduced vegetation.	Less than 25% of the catchment in introduced vegetation.	Between 25–49% of the catchment in introduced vegetation.	Between 50–74% of the catchment in introduced vegetation.	Over 75% of the catchment in introduced vegetation.	All the catchment in introduced vegetation.
Other pressures	Additional pressures should be scored based on their potential impact to the wetland type being monitored.					

Modifications to catchment hydrology

In the state (condition) indicators, the section on change in hydrological integrity focused on modifications to hydrology within wetlands. In addition, an important threat to wetlands is changes in the catchment hydrology that can lead to lowered regional groundwater tables or reduced surface water inputs. Features that increase this score include:

- drains in the catchment that impede groundwater flow in the wetland, weirs, and other structures that divert water from or into the catchment

- clearance of forest vegetation within the catchment (also likely to be picked up in water quality and % catchment in introduced vegetation sections)

- an increase in the extraction of groundwater from shallow bores

- an increase in the amount of impermeable surfaces within the catchment

Water quality within the catchment

Little monitoring of water quality is carried out in New Zealand wetlands but water quality data are available for streams throughout many regions and districts. Poor upstream water quality is a key indication of future deterioration in wetland condition. Increased nutrient inputs inevitably lead to changes in water quality, and vegetation composition and structure. These can be detected and monitored within the condition (state) indicators at the plot scale, but the threat can sometimes be identified earlier from catchment data. As well as surface water quality data, groundwater quality data can also be used, as can other stream water quality indices such as the macroinvertebrate community index and the stream health monitoring assessment kit.

Animal access

This can be based on direct observations during site visits (e.g., spoor, tracks, lack of fences in grazing areas) or can often be deduced from the nature of the catchment and the size of the wetland itself. Proximity and abundance of dwellings, and land use (e.g., farming, forestry, urbanised) would potentially harbour particular predator populations (feral and domestic) and would affect the score accordingly. It is also a feature that may require some background knowledge from previous studies, or knowledge of factors such as predator control operations in the vicinity, to score accurately.

Key undesirable species

Once key undesirable species have invaded and become established in wetlands, control and eradication can be a difficult and expensive exercise. Weed and pest control in wetlands is complicated by the heterogeneity of wetland environments, the practical difficulties of targeting control measures in such environments, and the presence of desirable non-target species that may be affected by control measures. As most undesirable species that enter wetlands usually do so only after being present in the catchment for some time, identification of key species before invasion is an important pressure indicator.

The relevant species here are those plant and animal species that are known to be invasive and damaging to ecological function and/or native biota of wetlands – the most common nationally significant examples are willows which are able to survive and out-compete native species in most wetland habitats. Table 7 provides a list of key undesirable species that are reasonably common. It would also be worthwhile consulting regional plant and animal pest lists for local information on regional key undesirable species, and reports on invasive species (e.g., Williams 1997). However, recent arrivals and certain other species are often not included, so talk with appropriate staff from either the Regional Council or the Department of Conservation. A number of species likely to have major impacts on wetlands are currently present within New Zealand but have not naturalised in wetland areas (e.g., *Phragmites australis*). These species are therefore potential threats but are not considered to be ecologically damaging enough at present to be included in Table 7.

Introduced species that do not directly invade and cause problems in wetlands are not included in this pressure – they are accounted for in the following pressure. Occasionally, a native species may also be a key undesirable species if present beyond its original range or in undesirably large numbers. Raupo is often regarded as a threat in restoration projects, as it can invade and exclude other native species, and excessive numbers of seabirds can also damage small remnant wetlands.

% catchment in introduced vegetation

For this feature the score is based on quantification from 0 = 0% to 5 = 100%. It is distinguished from the following category, which is based on activities in the catchment, by being based specifically on species in the catchment. The rationale for its inclusion is that the risk of new weed arrivals in a wetland is much greater if the catchment has introduced vegetation, and that predominantly introduced catchments are less likely to allow migration of desirable animal species. For restored and created wetlands, a native catchment provides a high likelihood of desirable species re-introducing themselves, whereas this is unlikely with a predominantly introduced catchment.

Table 7: Key undesirable species of palustrine and estuarine wetlands

Scientific name	Common name	Wetland type
Plants		
Alnus glutinosa (L.) Gartner	alder	Palustrine
Alternanthera philoxeroides (C.Mart.) Griseb.	alligator weed	Palustrine
Carex divisa Hudson		Estuarine
Carex ovalis Gooden.	oval sedge	Palustrine
Glyceria maxima (Hartman) Holmb.	reed sweetgrass	Palustrine
Iris pseudacorus L.	yellow flag iris	Palustrine
Juncus acutus L.	sharp rush	Estuarine
Juncus articulatus L.	jointed rush	Palustrine
Juncus bulbosus L.	bulbous rush	Palustrine
Juncus gerardii Loisel.		Estuarine
Juncus squarrosus L.	heath rush	Palustrine
Lycopus europaeus L.	gypsywort	Palustrine
Lythrum salicaria L.	purple loosestrife	Palustrine
Osmunda regalis L.	royal fern	Palustrine (fen/bog)
Paspalum distichum L.	Mercer grass	Palustrine
Paspalum vaginatum Sw.	seashore paspalum	Estuarine

Phalaris arundinacea L.	reed canary grass	Palustrine
Salix cinerea L.	grey willow	Palustrine
Salix fragilis L.	crack willow	Palustrine
Schedonorus phoenix Schreber	tall fescue	Palustrine
Schoenoplectus californicus (C.A.Mey) Palla	Californian club-rush	Estuarine
Spartina alterniflora Lois.	American spartina	Estuarine
Spartina anglica C.E. Hubb	spartina	Estuarine
Ugni molinae Turcz.	strawberry myrtle	Palustrine (bog)
Ulex europaeus L.	gorse	Palustrine
Vaccinium corymbosum L.	blueberry	Palustrine (bog)
Zizania latifolia (Griseb.) Stapf	Manchurian rice grass	Palustrine
Mammals		
Bos taurus Linneaus	cattle	Palustrine/Estuarine
Capra hircus Linnaeus	goat	Palustrine
Cervus elaphus scoticus Lonnberg	red deer	Palustrine
Felis cattus Linnaeus	cat	Palustrine/Estuarine
Macropus eugenii Desmarest	dama wallaby	Palustrine
Mustela erminea Linnaeus	stoat	Palustrine /Estuarine
Mustela furo Pocock	ferret	Palustrine/Estuarine
Mustela nivalis Linnaeus	weasel	Palustrine/Esturaine
Oryctolagus cuniculus Linnaeus	rabbit	Palustrine/Estuarine
Rattus norvegicus Erxleben	Norway rat	Palustrine/Estuarine
Rattus rattus Linnaeus	ship rat	Palustrine/Estuarine
Trichosurus vulpecula Kerr	possum	Palustrine
Fish		
Cyprinus carpio Linnaeus	koi carp	Palustrine
Gambusia affinis Baird and Girard	gambusia	Palustrine
Scardinius erythrophthalmus Linnaeus	rudd	Palustrine
Ameiurus nebulosus (Le Sueur)	catfish	Palustrine

Other pressures

Human activities in the landscape are important drivers of ecosystem condition in downstream wetland systems. Catchment issues that pose a clear threat to future condition are included in this component of the score. The most obvious contemporary issue in New Zealand is dairy conversions in rural areas; other examples are residential development, horticulture, mining, off-road vehicle use and logging activity. Surrounding gardens may also be an important threat, as many wetland weeds, such as purple loosestrife, are garden escapes.

6. Wetland Plot Sheet

6.1 Features

The Wetland Plot Sheet (Table 3) has three main components:

- The first section is for recording plant species presence, abundance (cover), and height within the various vegetation layers
- The second section is for determining indicator scores
- The third section is for recording physical and chemical parameters measured either in the field or from laboratory analysis of substrate and foliage samples

The plot sheet also has fields for recording location details, the field team leader, vegetation structure and composition (Atkinson naming system; see Appendix V), additional species in the vicinity growing in the same vegetation type, and other comments about the site.

Permanent plots are used, as they detect changes in condition at specific locations and yield quantitative data on biotic, physical, and chemical parameters. The plots are established in each of the main vegetation types within a wetland so that species:environmental relationships can be characterised. Vegetation types are determined at an appropriate scale following the mapping techniques outlines in Phase 1. In practice this may involve a simple pre-assessment of the number and extent of the main vegetation types using aerial photographs, high vantage points, and prior knowledge. Large wetland complexes may be pre-classified into separate wetland classes, e.g., Whangamarino wetland comprises large areas of swamp and bog, and these two classes exhibit markedly different conditions.

Plot locations are selected on the basis that they are a representative sample of the typical plant community within the vegetation type, e.g., characteristic species composition, uniform habitat, and plant cover as homogeneous as possible with no obvious community boundaries. A minimum of one plot per major vegetation type is suggested, although replicate sampling is preferable, particularly in the early stages of the survey when expertise is still developing. In addition, if the ecological pattern is heterogeneous, or a mosaic of vegetation types, an attempt should be made to sample the variation, by establishing several permanent plots.

The plot sheet can also be used as a basis for more intensive monitoring, with other components added as required, e.g., 5-minute bird counts, invertebrate sampling, photo-monitoring points. Plots can be systematically located at regular intervals across gradients, e.g., every 10 m along transects following a pollution gradient, or within stratified zones, e.g., rare plant communities, willow invasion zones. If intensive sampling is carried out in the same vegetation type, subsampling of some components may be appropriate, e.g., soil cores, plant foliage collected from one in five plots.

A plot size of 2m x 2m ($4m^2$) is suggested as this satisfies minimal sample area requirements for relatively short (<2m) and/or homogeneous wetland vegetation. During the field trials, this plot size proved to be relatively quick to sample, with minimal trampling or other damage because virtually all parts could be accessed from outside plot boundaries. However, in taller and more diverse vegetation, an area of $4m^2$ may not adequately represent the community species composition, and minimal area and/or running mean methods may need to be implemented to determine a more appropriate sample size. These methods are outlined in detail in Mueller-Dombois and Ellenberg (1974). The sample size will not affect comparisons between plots because vegetation indicators are based on relative measures such as % cover.

The soil and vegetation nutrient concentrations, and physico-chemical parameters, indicate the current condition of a wetland, or site within a wetland, as well as providing baseline data for monitoring change over time. Different wetland habitats (bogs, fens, swamps, estuaries) have characteristic ranges for these parameters and changes outside these ranges indicate a loss of condition. Interpretation of these data is discussed further in Appendix II. Soil parameters are potentially very useful for separating out various wetland classes, e.g., pH and total P levels are higher in swamps than bogs, whereas total C levels are highest in bogs. Some other indicators are also promising, for example, the use of foliage N:P ratio may prove to be a simple and relatively inexpensive indicator of nutrient status of the wetland. Additional data, however, are required to fill in the gaps, develop species: environmental models, and progress indicator development.

6.2 Methods

Pre-sampling

A list of equipment needed for field assessment is provided in Appendix III.

The first step is to determine the different vegetation zones or types present in the wetland appropriate to desired scale – using aerial photos, high vantage points and field reconnaissance – as outlined in Phase 1. For example, Lake Tomarata wetland has three main vegetation types: raupo reedland, manuka scrub, and *Empodisma* wirerushland.

Plot establishment

1. Within each vegetation zone, select an area typical of the zone and then randomly choose the starting point of a permanent plot (e.g., using random number tables).

2. Mark out the 2m x 2m plot (or a pre-determined larger area) using a tape measure. Permanently mark the four corners, e.g., with fibreglass (stock poles), wooden or plastic poles.

3. Fill in GPS coordinates and altitude. If you don’t have a GPS unit, fill in grid reference and altitude from NZMS 260 topographic maps.

4. Fill in III Structural class and IV Composition according to wetland classification (Atkinson 1985 naming system, e.g., III reedland, IV raupo; summarised in Appendix V). Note that the Atkinson name for the plot may differ from the Atkinson name for the vegetation zone because of issues of scale and vegetation heterogeneity.

Vegetation sampling

1. Decide on the number of vegetation layers (1, 2 or 3) represented in the plot. In all vegetation stands there will be at least one layer: canopy. If there are two layers, these will be canopy and groundcover. In tall, more complex vegetation, all other layers are combined into a middle subcanopy layer above a groundcover layer, which is usually around knee height (Fig. 1 in Appendix V; see also Myers et al. 1987). Note that the canopy and other vegetation layers are NOT equivalent to the fixed height tiers of the forest RECCE plot method.

2. *Canopy:* Estimate % cover for each of the canopy species (in top layer, i.e., bird’s eye or aerial photo view) within the plot, regardless of whether rooted in

the plot or not. If there is a canopy break, bare ground and litter are included (and recorded) in the canopy layer, not the groundcover layer. The total canopy cover (vegetation and substrate) should be 100%.

One approach is to choose the dominant species first and decide on its cover, e.g., does it cover more than 50% but less than 75% of the plot? For finer scale decisions, have in mind the area represented by key cover values. For example in a 2m x 2m plot, 1% cover is equivalent to a 20cm x 20cm square, and 10% cover is a 2m x 20cm rectangle. Species contributing less than 1% in the canopy are indicated by +. Measure height of tallest individual of each species based on foliage, not seed or flower heads.

3. Estimate % cover of each species in the remaining vegetation layer(s) as described above. The total % cover for each of the understorey layers will virtually always be less than 100%.

4. Indicate all introduced species by using an asterisk (*).

5. List any species in the vicinity that are growing in the same vegetation type (or zone) and were not encountered within the plot. Any notable species, e.g., threatened species, encountered on the way to the plot can be included in the Comments section.

Calculating vegetation-based plot indicator scores and condition index

Assign a score for each indicator based on the data in the vegetation layers and the 0–5 scale provided on the plot sheet. For the first indicator, add the % cover for all introduced species in the canopy column of the data table. Canopy % cover for plants may be less than 100% particularly if there are areas of bare substrate or litter. Note this in the ‘Specify and Comment’ section. The second indicator is the sum of the covers of all the introduced species in the subcanopy and groundcover columns. If this is greater than 100%, then record scale category 0. In the third row of the indicator table enter the proportion of introduced species in the total species list for the plot, expressed as a percentage. The fourth row is an estimate of the overall stress or dieback (a measure of health) exhibited by the plants using a scale of 0–5, where 5 = no obvious stress or dieback evident, and 0 = very high dieback or stress symptoms observed.

The vegetation-based condition index is the sum of the scores of the four indicators. The maximum total for the plot condition index is 20.

Substrate samples

Collect two substrate cores from within the plot by removing any vegetation and leaf litter at a coring site and heeling in a steel liner corer (suggested dimensions = 7cm diameter by 10cm deep) until flush with the bare ground surface. Carefully cut around outside of liner with a serrated knife, slice underneath, and lift out steel liner with intact core of substrate. Remove any excess material, particularly from bottom of core, so that core is an intact cylinder of substrate of set volume. Use thumbs to push substrate out of steel liner into labelled plastic bag trying not to lose any associated water – a separate bag for each sample.

Of the two samples, indicate which one should be used for bulk density analysis (the “better” one in terms of volume intactness) and supply core dimensions. Different-sized liners/covers may be used, e.g., a baked bean can with ends removed, but make sure size dimensions are supplied. Send as soon as possible (e.g., by courier) to a laboratory (preferably one accredited to ISO 17025 standards) for analysis of % water, bulk density, pH, conductivity, total C, total N, and total P (methods in Blakemore et al. 1987). Provide instructions that the two cores are to be combined as one sample for nutrient analysis. Store samples in fridge (or chilli bin in the field) wherever possible.

Foliage samples

Collect a small sample (about 5g; or a handful) of the tips of the foliage (young leaves/culms) or whole leaves of small-leafed plants of the dominant canopy species (one sample per plot). Avoid woody or flower parts and preferably collect sun rather than shade leaves. Put into labelled paper bag (or envelope – plant foliage may rot in a plastic bag) and send to a laboratory (as above) for analysis of total N and total P. If, when resampling, the dominant species has changed over time, collect the foliage of the former dominant, as well as the foliage of the new dominant.

Field physical parameters

Measure water table in the field by digging a small hole (you could use the hole from which the substrate core was collected) and letting water seep in until it attains equilibrium. Measure distance to water table from surface (indicate water above surface by ‘+’; see Appendix IV, Plots A1, A3). Measure water pH and conductivity if you have meters. Determine von Post by taking a handful of peat and squeezing it and assessing its attributes against a scale (Table 5; expanded in Appendix VI).

7. Calculating Wetland Condition Scores and Condition Index

7.1 Method

Wetland scores are assigned using a systematic comparison and evaluation process, supplemented by an evaluator’s intuitive sense of relative values (as in Myers et al. 1987). Guidelines for assigning scores for each indicator component are provided in Table 5.

The sub-index score for each indicator is the mean score of all its indicator components (sum of the indicator component scores divided by the number). Some components may not be relevant across all wetland types, e.g., von Post index is used only in bogs, and in non-bog systems will be excluded from the analysis. However, using the average allows comparisons between different types of wetland and enables deterioration or improvement in condition over time to be detected.

The total wetland condition index is the sum of all the component mean (sub-index) scores. The maximum total condition index is 25.

Three worked examples follow, showing how the scoring would be applied for wetlands with differing degrees of modification, ranging from almost pristine to highly damaged.

7.2 Wanganui River Flats, Hokitika District, West Coast

The Wanganui River Flats is an extensive swamp basin located on the true right bank of the Wanganui River, south of Hokitika. Relatively isolated from human impact, its dominant vegetation classes (sedgelands and shrublands) are intact and little other damage is evident. An example of scoring of the indicators for this site is shown in Table 8.

Table 8: Using the index to determine wetland condition: Wanganui River Flats

Indicator	**Indicator components**	**Specify and Comment**	**Score 0– 5**[1]	**Mean score**
Change in hydro-logical integrity	Impact of manmade structures	No man-made structures affecting hydrology.	5	**5**
	Water table depth	No evidence of any reduction in water table: species requiring high water tables present, regular flooding from river.	5	
	Dryland plant invasion	No dryland species present.	5	
Change in physico-chemical parameters	Fire damage	No damage currently evident.	5	**5**
	Degree of sedimentation/erosion	No unnatural erosion or sedimentation.	5	
	Nutrient levels	No data available but there are no anthropogenic nutrient sources in the vicinity.	5	
	von Post index	Not applicable.	-	
Change in ecosystem intactness	Loss in area of original wetland	None – wetland still occupies entire original basin within native forested upland and river.	5	**5**
	Connectivity barriers	None present.	5	
Change in browsing, predation and harvesting regimes	Damage by domestic or feral animals	No stock access. Potential access by deer and possums but no damage to soils or vegetation observed.	5	**4.67**
	Introduced predator impacts on wildlife	No data, but some predator impacts on terrestrial birdlife likely.	4	
	Harvesting levels	None.	5	
Change in dominance of native plants	Introduced plant canopy cover	Low. Only one introduced species (*Juncus canadensis*) present, which is abundant but never dominant in any vegetation class.	4	**4.5**
	Introduced plant understorey cover	Extremely low. *J. canadensis* absent under forested areas.	5	
Total wetland condition index /25				**24.17**

[1]Assign degree of modification as follows: 0=extreme, 1=v high, 2=high, 3=medium, 4=low, 5=v low/none

7.3 Moanatuatua Bog, Waikato

Moanatuatua Bog has undergone a loss of biodiversity over the past 30 years (including a 20% decline in vascular species), but other wetland functions are still relatively intact, e.g., peat forming processes, expansion of restiad vegetation (Clarkson et al. 1999). An example of scoring the indicators for this site is shown in Table 9.

Table 9: Using the index to determine wetland condition: Moanatuatua Bog

Indicator	**Indicator components**	**Specify and Comment**	**Score 0– 5[1]**	**Mean score**
Change in hydro-logical integrity	Impact of manmade structures	Ring-drained; some old drains in bog; small size and rectangular shape make it susceptible to draw down & regional lowering; drainage began 1930s.	1	**2**
	Water table depth	Over past 30 yrs data shows decline of 0.5–1m. Loss of species requiring high water table, e.g., *Sphagnum cristatum*, *Utricularia delicatula*, *Corybas carsei*, *Lycopodiella serpentina.*	1	
	Dryland plant invasion	Low. Confined to margins.	4	
Change in physico-chemical parameters	Fire damage	Last fire in 1972; affected 40% of wetland. No damage currently evident.	5	**4**
	Degree of sedimentation/erosion	N/A raised peat bog is rain fed.	-	
	Nutrient levels	P levels elevated. N and K marginally elevated, some fertiliser drift from adjacent farms.	3	
	von Post index	Decomposition low, peat-forming restiads dominate.	4	
Change in ecosystem intactness	Loss in area of original wetland	Only 140ha (2% of former 7000ha) of 'original' peat bog left. Converted to dairy or cropping farms.	1	**1**
	Connectivity barriers	Now isolated islands in a sea of pasture; few minor connections to Waikato River.	1	
Change in browsing, predation and harvesting regimes	Damage by domestic or feral animals	Stock excluded by fences and ditches. Minor browsing of orchids and young growth by possums, rabbits, and occasionally turkeys.	4	**4**
	Introduced predator impacts on wildlife	Cats, possums, hedgehogs, stoats prey on fernbird/eggs. Thick growth deters feral animals. Recent control programme now finished. Med-high re-invasion.	3	
	Harvesting levels	None.	5	
Change in dominance of native plants	Introduced plant canopy cover	Low. Introduced spp confined to within 1–2m of margins. Some grey willow along drains.	4	**4.5**
	Introduced plant understorey cover	Very low. Understorey plants virtually all native. An occasional ephemeral annual present.	5	
Total wetland condition index /25				**15.5**

[1]Assign degree of modification as follows: 0=extreme, 1=v high, 2=high, 3=medium, 4=low, 5=v low/none

7.4 Cockayne Reserve, Christchurch

Cockayne Reserve is an isolated wetland fragment within Christchurch City, located on the true left bank of the Avon River. In pre-European times it was a mosaic of swamp and estuarine vegetation, fed by the extensive freshwater dune swales upstream and the brackish Avon River and Avon-Heathcote Estuary downstream. It is now highly modified by surrounding residential development, with a history of fire, eutrophication, and altered hydrology. It is artificially divided into a freshwater area (approx. ⅔ of total area) and an estuarine area by a stopbank.

Table 10 shows its condition in 1982, after being degraded by repeated recent fires and the spread of weeds such as tall fescue and yellow flag iris:

Table 10. Using the index to determine wetland condition: Cockayne Reserve 1982

Indicator	Indicator components	Specify and Comment	Score 0– 5[1]	Mean score
Change in hydro-logical integrity	Impact of manmade structures	Extreme: Stopbanks, roads, housing have completely modified original hydrology. One small connection to estuary remains.	1	**0.67**
	Water table depth	No water supply.	0	
	Dryland plant invasion	Dry soils have allowed extensive invasion.	1	
Change in physico-chemical parameters	Fire damage	Entire area repeatedly burnt due to vandalism.	0	**0.5**
	Degree of sedimentation/erosion	Little wetland character now remains in soils.	1	
	Nutrient levels	No data available.	-	
	von Post index	Not applicable	-	
Change in ecosystem intactness	Loss in area of original wetland	Extreme – almost all natural character lost.	0	**0.5**
	Connectivity barriers	Extreme – no connections upstream, many barriers downstream.	1	
Change in browsing, predation and harvesting regimes	Damage by domestic or feral animals	No stock access. Potential access by small feral animals but no evidence of impacts.	5	**3.67**
	Introduced predator impacts on wildlife	Little habitat remains for wildlife, and drying of wetland allows full access to predators.	1	
	Harvesting levels	None.	5	
Change in dominance of native plants	Introduced plant canopy cover	Tall fescue and yellow flag iris have almost replaced all native species.	1	**1**
	Introduced plant understorey cover	Tall fescue and yellow flag iris have almost replaced all native species.	1	
Total wetland condition index /25				**6.34**

[1]Assign degree of modification as follows: 0=extreme, 1=v high, 2=high, 3=medium, 4=low, 5=v low/none

Table 11. Using the index to determine wetland condition: Cockayne Reserve 2000

Indicator	Indicator components	Specify and Comment	Score 0– 5[1]	Mean score
Change in hydro-logical integrity	Impact of manmade structures	Very high: Stopbanks, roads, housing have completely modified original hydrology. Artificial bore supplies freshwater area, one artificial channel links estuarine area to river.	1	**2**
	Water table depth	Highly modified: dry in some areas and stagnant in others.	2	
	Dryland plant invasion	Dryland plants now a minor component.	3	

Change in physico-chemical parameters	Fire damage	Entire area burned in the past but fire-sensitive species recovering over most of area.	3	**2**
	Degree of sedimentation/erosion	Very high: excessive *Typha* growth has been allowed to accumulate a deep layer of anaerobic sediment.	1	
	Nutrient levels	Both N and P highly elevated in soils and vegetation.	2	
	von Post index	Not applicable	-	
Change in ecosystem intactness	Loss in area of original wetland	Extreme – all natural original vegetation destroyed in the past and current system is artefact of management interventions.	0	**0.5**
	Connectivity barriers	Very high – freshwater section isolated entirely from other waterways, estuarine connection limited.	1	
Change in browsing, predation and harvesting regimes	Damage by domestic or feral animals	No stock access. Potential access by small feral animals but no evidence of impacts.	5	**4**
	Introduced predator impacts on wildlife	Evidence of predator trails (stoats) in and around wetland, but some native birdlife remains.	2	
	Harvesting levels	None	5	
Change in dominance of native plants	Introduced plant canopy cover	Low in estuarine area but tall fescue is co-dominant in freshwater area.	4	**3**
	Introduced plant understorey cover	High in both areas, particularly freshwater where many adventive species are present. Purple loosestrife and yellow flag iris both common.	2	
Total wetland condition index /25				**11.5**

[1]Assign degree of modification as follows: 0=extreme, 1=v high, 2=high, 3=medium, 4=low, 5=v low/none

By 2000 (Table 11), considerable recovery had occurred due to management interventions. Planting of native species and restoration of a water supply had restored some natural character, although weeds were still widespread. However, poor water exchange had allowed the raupo biomass to increase dramatically, leading to excessive sedimentation and in-filling. The score therefore reflects an overall improvement but identifies those issues still causing problems.

8. Calculating Wetland Pressure Scores and Index

Wetland pressures are scored on a scale of 0–5, following the guidelines in Table 6. The wetland pressure index is the sum of the six wetland-pressure scores, and has a maximum total of 30. A high value indicates high pressures and stresses on the wetland environment, which potentially can cause changes in condition (state). It is important to assess these pressures both individually and as a total index to identify what and where the major pressures are. The pressure scores and total index are used as a tool to signal where resources and effort should be targeted within the wider monitoring programme. Examples of scoring pressures within some of the field trial wetlands are provided in Appendix IV.

9. Analysing Change

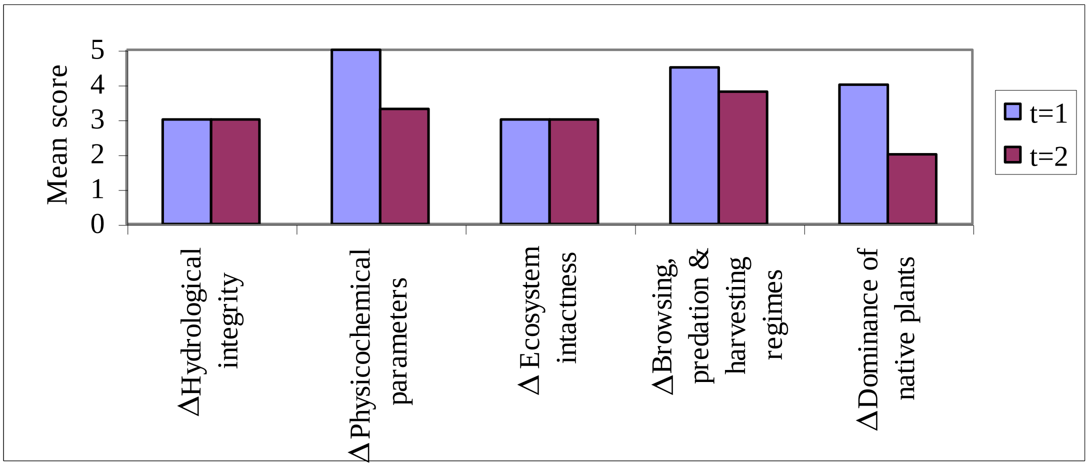
Change in condition may be analysed at different scales and within different layers of the classification system (as in Phase 1). The monitoring framework used may be Environmental Domain, Ecological District, council administration boundary, bioclimatic zone, wetland class, vegetation type, or any other similar ecological grouping. Wetland indicators may also be analysed at different levels or any combination of levels from the hierarchical classification depending on the aim of the monitoring project, e.g., total score index, individual indicator sub-index, or separate component indicator score. Similar levels may be used for analysis of indicators and data at the plot scale. Monitoring practitioners should develop their own techniques for interpretation of data and analysing change, designed to meet the needs of their specific monitoring projects. Some examples of different ways of analysing change in condition are as follows:

- If organisations wanted to assess the effectiveness of a fencing/stock exclusion education programme then the indicator component 'B1: Damage by domestic or feral animals' would be compared at time=1 (pre-programme) and t=2 (post-programme).

- Willow has newly arrived in a district and has started to invade wetlands. Swamps, being of relatively high fertility, are the most susceptible wetland class, so plot data for swamps throughout the district are analysed. Comparison of the plot indicator 'Canopy % cover introduced species' at t=1 and t=2 reveals the percent of swamps that have declined in condition (and the percent improved and percent unchanged or steady). The extent of the decline can be calculated from the raw quantitative data. These plot data, together with reconnaissance and other information (e.g., aerial photo comparisons at t=1 and t=2), provide the basis for assessing the wetland indicator component 'D1: Introduced plant canopy cover'.

- Changes in indicator sub index (or indicator component scores) may be presented in several ways, e.g., as radar charts or bar graphs using simple graphing packages such as Microsoft Excel. Fig. 2 illustrates two ways of presenting the same data. These should also be accompanied by the raw data, e.g., indicator sub-indices or indicator component scores.

- At a district/region-wide scale, a summary of the trend in wetland condition may be required to show what proportion of the number of wetlands is deteriorating, improving or remaining steady. A pie chart based on the overall wetland index score at t=1 and t=2 effectively illustrates wetland condition (Fig. 3). This technique could also be applied to area data (using wetland extent information from Phase 1) to show the trends in condition for the total wetland area within the region. Other appropriate levels for illustrating and comparing changes include the wetland system (palustrine, estuarine), class (marsh, swamp, fen, bog), vegetation type, or other suitable grouping.



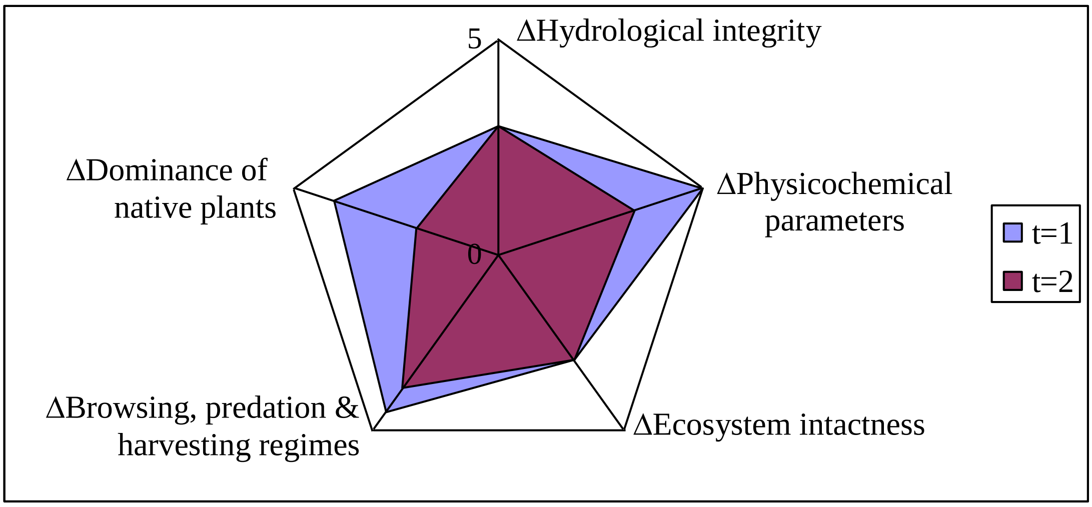


Figure 2: Representing change in condition over time using bar graphs (above) and radar charts (below: pentagon represents the unmodified condition). In both cases, t=1 represents an initial sampling time and t=2 a later sampling time. Deterioration in scores for changes in physicochemical parameters, browsing, predation & harvesting levels, and dominance of native plants, have lowered the overall condition index from 19.5 to 15.1.

- The condition and pressure indicators could be used together to determine priorities for wetland management. Wetlands that had a high condition index and a high pressure score would be obvious candidates for targeting resources or further monitoring.

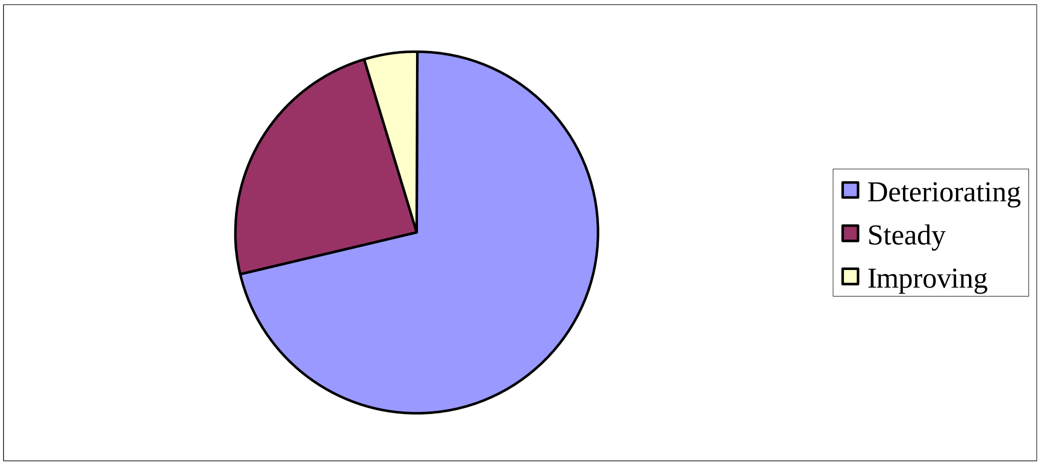


Figure 3: Pie chart showing use of the index to represent change in wetland condition at district or region-wide scales

10. Where to from here?

A national wetland database has recently been established to utilise the monitoring data collected from the 15 wetlands visited during indicator development. This, however, is only a start, and much more information is required to encompass the full range of geographical and altitudinal range, size, class, vegetation composition and structure, and degree of modification inherent in wetlands throughout New Zealand. Over the next few years we will endeavour to fill some of the gaps. The aim of the database is to:

- be a repository for information on wetlands from throughout New Zealand
- provide quantitative data for determination of species:environmental relationships within the different classes of wetland

The wetland database information will be used mainly to develop understanding of the essential properties of wetlands, which will assist in progressing indicator development and in determining critical limits that can be used for setting goals and measuring performance.

Endusers who use the monitoring methods outlined in this handbook are encouraged to contribute to the national wetland database. Please post copies of the filled-in plot and wetland sheets to Wetland Database, Landcare Research, Private Bag 3127, Hamilton, or email attached files to wetlanddatabase@landcareresearch.co.nz. Requests for copies of the wetland and plot field sheets and any queries, comments or suggestions should also be directed to these addresses.

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Appendix I: Maori Environmental Monitoring Sheet

MAORI INDICATORS – WETLAND MONITORING FORM

Name of wetland:
Date:
People involved in monitoring:

WHAT'S CAUSING THE PROBLEMS?

% area of land uses/riparian factors affecting Cultural Values

0 = 0%	1 = 1–20%	2 = 21–40%	3 = 41–60%	4 = 61 – 80%	5 = 81–100%

No. of point (sites) sources of pollution degrading ***te Mauri***

0 = 0	1 = (1–2)	2 = (3–5)	3 = (6–9)	4 = (10–14)	5 = (>15)

Degree of modification (drainage, water table, burning, in-flows, out-flows) degrading ***te Mauri***

1 = low	1 = moderate	3 = high	2 = v.high	5 = extreme

No. of exotic (introduced, foreign) plants, algae, animals, fish, birds (pest types) affecting Cultural Values

0 = 0	1 = (1–2)	2 (3–5)	3 (6–9)	4 (10–14)	5 (>15)

TAONGA AND MAURI? (Maori information about the wetland, its attributes)

No. of ***taonga*** species (flora and fauna) within wetland

0 = 0	1 = (1–2)	2 (3–5)	3 (6–9)	4 (10–14)	5 (>15)

% area of ***taonga*** plants within total wetland

0 = 0%	1 = 1–20%	2 = 21–0%	3 = 41–60%	4 = 61–80%	5 = 81–100%

% area of exotic (introduced, foreign) plants covering total wetland

0 = 0	1 = 1–20%	2 = 21–40%	3 = 41–60%	4 = 61–80%	5 = 81–100%

No. of cultural sites within or adjacent to wetland

0 = 0	1 = (1–2)	2 (3–5)	3 (6–9)	4 (10–14)	5 (>15)

Assessment of ***te Mauri*** (scale)

1 = weak or low	2 = average or moderate	3 = strong or high

TRENDS/CHANGE/WETLAND GETTING BETTER OR WORSE?

Previous assessment date: Present assessment date:

Change in No. of ***taonga*** (flora and fauna) species within total wetland area
(+, same or &)

0 = 0	1 = (1–2)	2 (3–5)	3 (6–9)	4 (10–14)	5 (>15)

Change in % area of ***taonga*** plants within total wetland area
(+, same or &)

0 = 0%	1 = 1–20%	2 = 21–40%	3 = 41–60%	4 = 61–80%	5 = 81–100%

Change in % area of exotic (introduced, foreign) plants covering total wetland
(+, same or &)

0 = 0%	1 = 1–20%	2 = 21–40%	3 = 41– 60%	4 = 61–80%	5 = 81–100%

No of **cultural sites protected** within or adjacent to wetland

0 = 0	1 = (1–2)	2 (3–5)	3 (6–9)	4 (1–14)	5 (>15)

Assessment of change in ***te Mauri***

1 = worse	2 = same	3 = improvement

Or

1 = negative/fast	2 = negative/slow	3 = neutral	4 = positive/slow	5 = positive/fast

Other comments about the wetland (e.g., use of wetland, customary access, customary rights, fitness for traditional cultural usage)

Source: Harmsworth (2002)

Appendix II: Interpretation of Soil and Plant Data for Monitoring of Nutrient Status and Eutrophication

Background

Nutrient enrichment (eutrophication) can dramatically alter vegetation composition, health, and habitat value in wetlands, and is arguably second only to hydrological disturbance as a cause of loss of wetland condition in New Zealand. Point source discharges of nutrients and diffuse nutrient run-off are widely recognised as important problems affecting lake and river ecosystems, but their effects on wetland ecosystems have received less attention. Tools for monitoring eutrophication have not been developed for wetlands in New Zealand, and this section describes the use of soil and plant nutrient concentrations as indicators of nutrient enrichment, and for monitoring of nutrient enrichment over time.

Many studies overseas have shown that nutrient supply has a major influence on the composition, structure, productivity and health of wetland vegetation. Mineral nutrients have been described as 'the fundamental currency of vegetation processes at scales from the individual to ecosystems and landscapes' (Grime et al. 1997). Changes in nutrient loads into wetlands increase soil nutrient concentrations, causing shifts in species composition because species vary in their ability to cope with different nutrient availabilities. In the most oligotrophic (low nutrient) wetlands, species diversity is low as the vegetation is dominated by the few species that are highly specialised for coping with low nutrient resources. Maximum species diversity occurs at intermediate nutrient regimes, where species are competing for nutrients but growth is still limited by nutrient availability. Species diversity declines again under high fertility, where nutrients are no longer growth limiting, productivity is high, and a small number of tall, productive species out-compete others for light.

Species composition in plots can therefore provide some indirect information about nutrient limitation, and changes in composition in plots over time can potentially be interpreted as an indication of change in nutrient regime. However, distinguishing eutrophication from other disturbance factors that alter composition can be difficult, let alone establishing causality. Also, changes in species composition may not occur for some time after the nutrient regime is altered – lags of several years are common – so their value in early detection of eutrophication may be limited. To provide tools for early detection and monitoring of eutrophication, before shifts in species composition, we have attempted to adapt the now extensive overseas literature on interpretation of soil and plant nutrient concentrations for detection of nutrient limitation in New Zealand.

Soil nutrient concentrations

Changes in soil chemistry and soil nutrient content are widely used to monitor inputs of dissolved and particulate nutrients into wetlands. Dissolved nutrients in standing water can be used in deeper wetlands, and in these habitats can often be interpreted in similar ways to nutrient monitoring programmes in lake and river ecosystems. However, soil sampling is more generally applicable in wetlands, which often have water tables at or below the soil surface. In addition, the dominant primary producers in wetlands are usually higher plants, and soil sampling gives a better indication of nutrient availability and eutrophication for these environments than water sampling.

Soil pH is one of the simplest and most revealing attributes for detecting environmental change. Rainwater-fed bogs generally have lowest soil pH (usually <4.0), groundwater-fed freshwater fens and swamps between pH 4.0–pH 6.0, and estuarine systems usually have circumneutral soil pH (pH 6.0–8.0). These ranges are evident in Table 13 for New Zealand sites in the field trials. Values higher than pH 4.0 in some bog vegetation were at sites with groundwater input, e.g., Lake Tomarata. Values below pH 6.0 at some estuarine sites were from marginal areas supporting non-halophytic species, e.g., *Cordyline australis* at Omaha and *Phormium tenax* at Pauatahanui, where groundwater influences were present. Changes in soil pH indicate hydrological change, e.g., intrusions of groundwater into bogs due to catchment modification.

Table 13: Soil parameters for wetlands sampled in field trials, by vegetation type (number of sites in brackets in site row, mean value with range in brackets in parameter rows). TC = Total carbon, TN = total nitrogen, TP = Total phosphorus, and Available P is P extracted by the 0.5 M H_2SO_4-P method.

	Bogs (6)	Swamps (17)	Estuaries (8)	All sites (31)
Soil pH	4.0 (3.7–4.4)	5.2 (4.1–5.9)	6.4 (4.9–7.1)	5.3 (3.7–7.1)
TC (mg cm^{-3})	92.7 (24.1–239.8)	39.8 (5.2–100.6)	18.9 (7.1–36.7)	54.6 (5.2–239.8)
TN (mg cm^{-3})	0.82 (0.02–1.83)	2.12 (1.15–3.24)	1.22 (0.63–2.53)	2.32 (0.02–13.3)
TP (mg cm^{-3})	0.08 (0.01–0.20)	0.28 (0.15–0.59)	0.31 (0.15–0.64)	0.22 (0.01–0.64)
C:N	48.5 (35.9–79.7)	18.0 (14.2–30.6)	16.6 (11.2–23.2)	23.1 (11.2–79.7)
C:P	1904 (533–4221)	163 (45–435)	69 (15–137)	447 (69–4221)
N:P	39.0 (20.6–81.6)	9.1 (4.0–20.6)	4.6 (0.7–8.1)	13.2 (0.7–81.6)
Available P (μg cm^{-3})	15.9 (3.9–35.1)	87.5 (17.6–187.4)	160.1 (61.0–557.3)	90.2 (3.9–557.3)

Table 13 also gives nutrient concentrations from the field trials for the three wetland classes. Total Carbon is a measure of organic matter content in the soil, and is generally higher in bogs than in swamps and estuaries. The lowest values are for sandy substrates with little organic matter accumulation (e.g., seagrass beds at Pauatahanui). Total nitrogen and phosphorus concentrations vary considerably within and between sites, and do not differ greatly between classes, except that P is generally lower in bogs. Instead, detecting eutrophication and environmental change is often based on the ratios of these nutrients, which are more characteristic of classes and vegetation types. Hence, in the data in Table 13, C:N ratios are higher in bogs than swamps or estuaries, and C:P and N:P ratios are highest in bogs, followed by swamps and then estuaries. These patterns reflect the nature of the organic matter accumulating in the soil as well as mineral contents and other nutrient sources.

The use of total nutrients is often questioned in eutrophication monitoring, especially for predicting vegetation composition changes or algal blooms, because not all fractions are equally bioavailable. Other nutrient analyses can be used, such as the H_2SO_4-P method used in the field trials, which is sometimes regarded as a better measure of plant-available P than TP. The low P availability in bogs also appears with this method, but it also indicates higher availability in estuaries, which may be associated with the larger mineral content of estuarine soils. Mineral material often has significant quantities of loosely adsorbed inorganic phosphorus that is readily bioavailable.

For the purposes of monitoring, changes in these ratios within a site over time are widely accepted as indicators of changes in nutrient loading or nutrient source. In bogs, changes in soil

N:P ratio are particularly indicative of external nutrient loading, but all three ratios can change depending on the nature of the nutrient input.

Plant nutrient concentrations

Fertilisation experiments are the most straightforward methods to detect nutrient limitation in the field. However, they are usually laborious and too expensive to use on a wide scale, and responses to sudden increases in nutrient supply after fertilisation may differ from those that follow the more gradual increases typical of changes in catchment nutrient loading. Instead, an indication of the nature of nutrient limitation and changes in nutrient loading can be estimated from plant nutrient concentrations. Although there are some drawbacks, a number of European studies have recently shown this method does have value, provided some caution is taken in data interpretation.

N and P are the nutrients usually most likely to limit plant growth in wetlands, and these methods are based on the concentrations of each and on the ratio of the two in plant tissue. Concentrations of N and P in plant tissues result from a combination of both nutrient availability and plant requirements for healthy growth, and generally increase as growth conditions become more eutrophic. The N:P ratio has proved to be a particularly useful predictor of which nutrient is limiting in oligotrophic sites, where tissue ratios of N:P <14 indicate N limitation and N:P >16 indicate P-limitation, with intermediate values indicating co-limitation by both N and P (Koerselman and Meuleman 1996). In more eutrophic sites, when tissue nutrient concentrations are higher, the ratios are less predictive because concentrations of one or both nutrients may exceed growth-limiting thresholds. Most current data suggest a credible indication of nutrient limitation can be seen by plotting tissue [N] vs tissue [P] (Willby et al. 2001), as follows (Fig. 4):

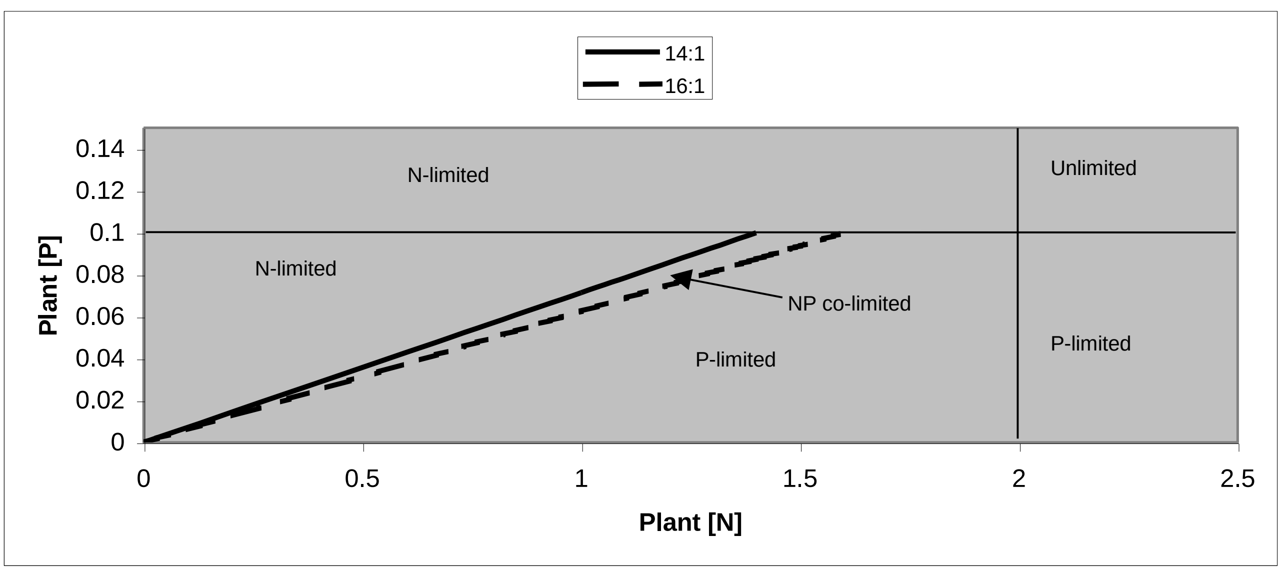

Fig 4. Theoretical interpretation of the nature of nutrient limitation of wetland vegetation based on tissue nutrient concentrations. Concentrations are in %dry wt. Modified from Willby et al. (2001).

- If [N] >2% dry wt and [P] >0.1% dry wt, growth is unlimited by N and P availability
- Growth is N-limited if [N] <2% dry wt and [P] >0.1% dry wt.
- Growth is P-limited if [N] >2% dry wt and [P] <0.1% dry wt.
- If [N] <2% dry wt and [P] <0.1% dry wt, the N:P ratio can be used. N:P <14 indicates N limitation and N:P >16 indicates P-limitation

The thresholds are approximate only; factors causing variability include:

- Species have different nutrient requirements and can differ in the degree to which they accumulate nutrients in excess of growth requirements. When grown in the same soil, herbaceous species with short life cycles generally have the highest nutrient concentrations, slow-growing stress-tolerant species the lowest concentrations, and tall-growing, competitive perennials intermediate concentrations.

- There are some seasonal changes in nutrient concentrations and changes due to the growth stage of the plant, especially in those species that have a high annual biomass turnover or senesce in winter.

- More conservative N:P ratios are sometimes applied at low concentrations, e.g., Boeye et al. (1997) suggest a ratio of 20:1 rather than 16:1 for conclusively showing P limitation. Slightly different upper thresholds (e.g., [N] >1.3% or 1.5%, [P] >0.11%) have also been suggested.

Nevertheless, most recent studies show this approach is highly accurate in predicting the nature of nutrient limitation in wetlands, provided these factors are taken into account. Differences between species are not usually large enough to prevent reliable conclusions about the nature of nutrient limitation or obscure eutrophication trends. The dominant species in the plot is always chosen, as its nutrient concentrations are most representative of the vegetation as a whole. Seasonal and growth stage variations can be minimised by (i) always selecting healthy green tissue without any visible signs of senescence, and (ii) restricting sampling to the active growing season, i.e. between November and February for most regions in New Zealand. Flowering shoots should also be avoided, as plants often re-mobilise nutrients internally when flowering.

Vegetation N and P concentrations in New Zealand sites

The validity of this method for New Zealand wetlands was tested during the field trials from sampling of the dominant species in the 2 × 2m plots. Fig. 5 shows all data from the field trials, plotted as [N] vs [P] as shown above.

Large differences in nutrient content were present. Only three of the plots had vegetation that had escaped nutrient limitation. Most of the plots (61%) showed some form of N limitation or, in one case, NP co-limitation. The remaining 29%, all with very low concentrations of both N and P, showed P-limitation. Very similar patterns – predominant N-limitation except in very oligotrophic sites – are seen in wetlands in temperate habitats elsewhere, as is the absence of any plots in the strongly P-limited quadrant of Fig. 5A. Tissues with [N] >2% dry wt and [P] <0.1% dry wt occur most often in tropical ecosystems.

Nutrient availability differs both within and between wetlands, and vegetation N and P contents can detect differences on both scales. In Table 14, the 31 vegetation samples are separated into the four classes of nutrient limitation from Fig. 5A. Unlimited vegetation and N-limited vegetation with high tissue nutrient concentrations were mainly associated with urban and rural wetlands subject to nutrient enrichment, such as Travis Swamp, the Cockayne Reserve and Whangamarino. Low nutrient concentrations, especially P-limited vegetation, occurred mainly in oligotrophic sites such as Waituna Lagoon and Awarua Bog, or Lake Taharoa. Differences within sites are also evident in Table 14, with bog plots having lower nutrient concentrations than rurally influenced groundwater-fed plots at sites such as Lake Tomarata. Marine influences also tend to increase nutrient concentrations (e.g., Pauatahanui), as seawater is high in both inorganic N and P.

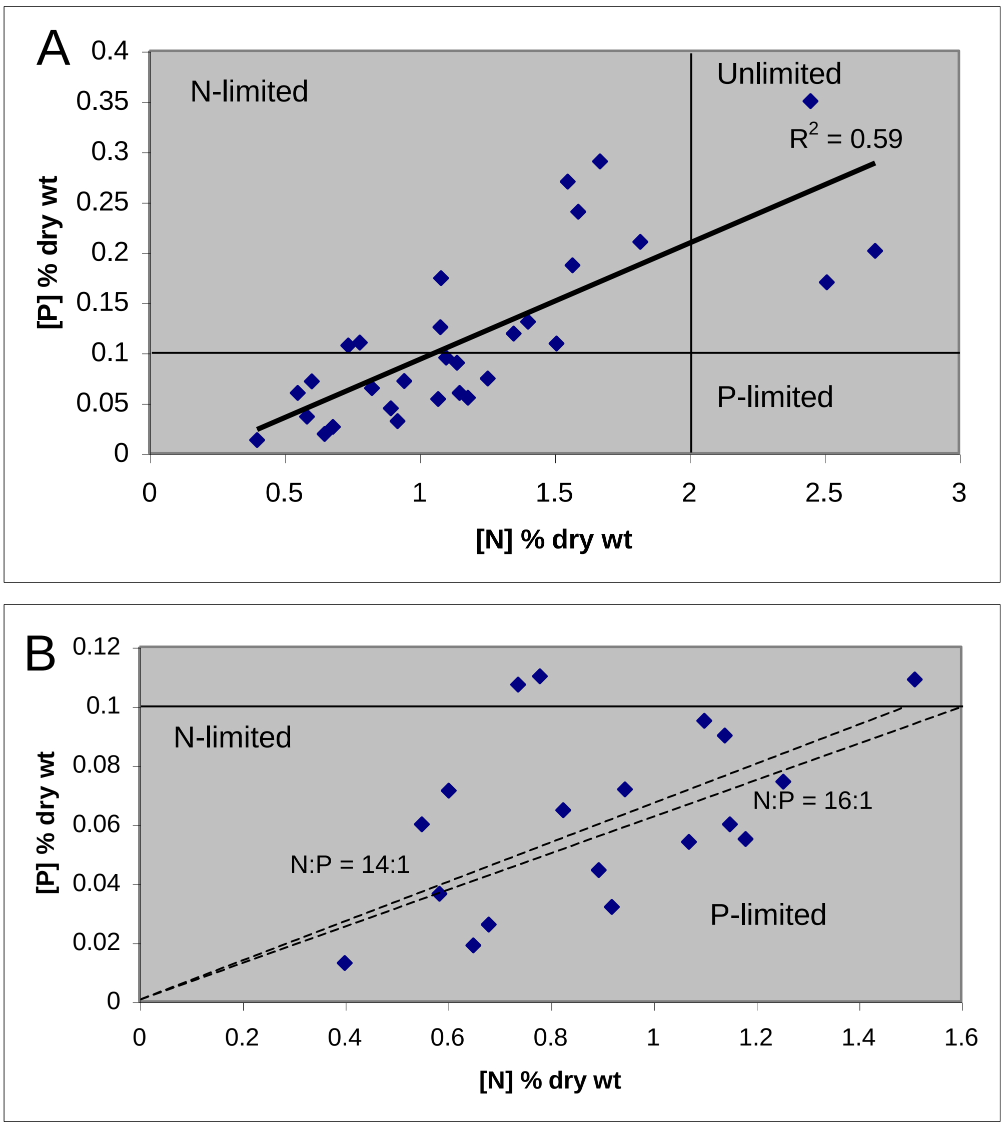

Fig 5. A: Plant tissue N vs P correlation with regard to critical nutrient concentrations and the N:P ratio (n = 31, 14 wetlands and 18 species). The regression line is significant at P = 0.001, and its slope (y = 0.12x – 0.02) is consistent with optimum N:P ratios in wetland plants of 10–12 (Aerts and Chapin 2000). Plots falling in the upper right sector are regarded as unlimited and in the upper left sector are probably only limited by N. The lower left sector is expanded in B. Within the range of potential limitation by both N and P the critical ratio for N limitation is indicated by 14:1 and for P limitation is 16:1.

Table 14: Differences in nutrient limitation between sites inferred from vegetation N:P ratios

Site	P-limited vegetation	N-limited vegetation		Unlimited vegetation
		[P] <0.1%	[P] >0.1%	
Lake Ohia	*Schoenus brevifolius*			
Waitangi Forest	*Baumea rubiginosa*			
Waiparaheka	*Gleichenia dicarpa*			
Lake Taharoa	*Apodasmia similis*			
Maitahi	*Baumea teretifolia*			
Lake Tomarata	*Empodisma minus*	*Leptospermum scoparium*		*Typha orientalis*
Whangamarino			*Carex gaudichaudiana* *L. scoparium* *Carex virgata*	
Kaituna	*Gahnia xanthocarpa*	*Cordyline australis*	*C. virgata*	
Pauatahanui		*Juncus kraussii*	*Zostera novaezelandica* *P. tenax*	*Schedonorus phoenix*
Travis			*Carex secta,* *T. orientalis*	
Cockayne			*C. secta*	*T. orientalis*
Okarito Lagoon	*A. similis* (NP co-limited)		*G. xanthocarpa* *J. kraussii*	
Waituna Lagoon	*A. similis*	*Phormium tenax*		
Awarua	*E. minus* (plot 3)	*E. minus* (plot 1) *L. scoparium* *Donatia novaezelandiae*		

Comparisons using individual species

The nature of nutrient limitation in wetlands can be relatively quickly established with a survey of vegetation N and P contents, even if there is a range of species in the samples. Using multiple species is often necessary because of the vegetation heterogeneity within a site, or between sites. However, monitoring with key individual species can be particularly powerful, as the inter-specific variation is avoided. In oligotrophic sites, the vegetation is often dominated by one species or a very small number of species, and these sites are often those where protection from eutrophication is important. Fig. 6 shows a dataset for *Empodisma minus* from rainwater-fed peat bogs in the Waikato Region, where it is the dominant component of the vegetation. These peat bogs have very low nutrient inputs and the vegetation N and P concentrations are very low. The growth-limiting nutrient is usually P and sites not impacted by nutrient enrichment generally have a very consistent tissue [P] in the region of 0.010% dry wt. The eutrophicated sites in Fig. 6 are near the edge of these bog remnants, subject to some nutrient enrichment from adjacent farmland. In this dataset, the tissue N and P contents are picking up the earliest signs of eutrophication, long before any visual change in the vegetation such as invasion by other species can be detected. Although this dataset has been produced from spatial sampling at one time in these bogs, similar graphs can be produced using temporal datasets that show a shift in nutrient contents over time as eutrophication progresses. *E. minus* is a useful species for monitoring as its tissues continue to show higher nutrient concentrations in sites with greater nutrient input – the samples from Lake Tomarata and Awarua Bog all had [N] >0.6% and [P] >0.05%.

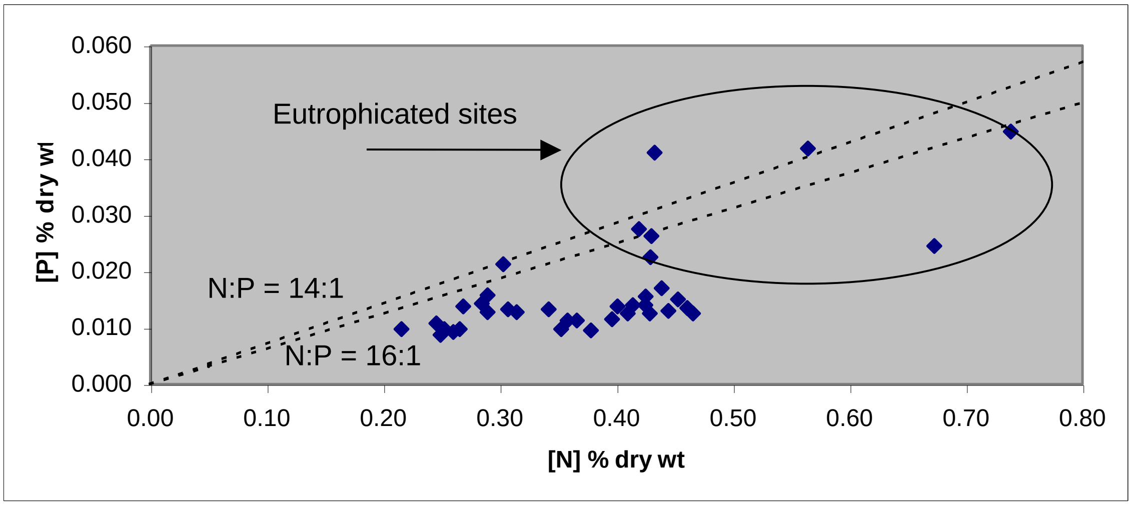

Figure 6: Tissue N:P ratios in *Empodisma minus* from rainwater-fed peat bogs in the Waikato. The N:P = 14:1 and N:P = 16:1 lines demarcate N and P limitation. Sites subject to nutrient enrichment indicated in circled region.

Eutrophication of groundwater-fed wetlands, where the nutrient availability in pristine sites is considerably higher than in bogs, can also be followed from changes in individual species. Fig. 7 shows a dataset for *Typha orientalis* in Canterbury, comparing nutrient concentrations between upland swamps with little nutrient enrichment vs eutrophicated lowland swamps. These swamps are usually N-limited even when in pristine nutrient regimes (note how much higher the concentrations are than for the peat bogs in Fig. 6, even in the least eutrophic sites), but the effects of nutrient enrichment in the urban and rural sites is clear. Again, this is a spatially based dataset, comparing nutrient enrichment between sites, but similar datasets could be produced for monitoring eutrophication over time.

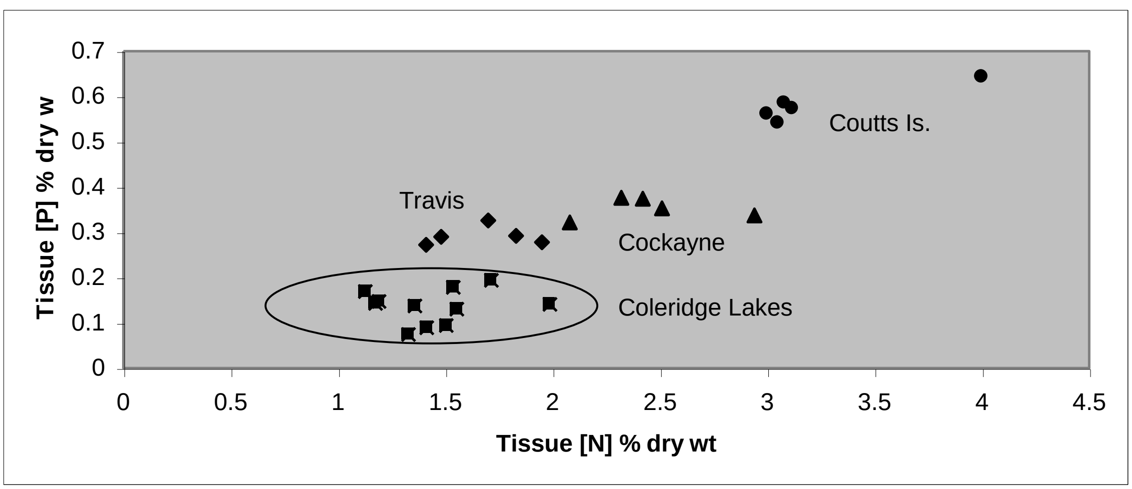

Figure 7: Tissue N and P concentrations for *Typha orientalis* from four wetlands in Canterbury. The 'Coleridge Lakes' (squares, ringed) lie in a high-country valley with a low-intensity sheep grazing catchment, Travis Swamp (diamonds) and Cockayne Reserve (triangles) in Christchurch have residential catchments, and Coutts Island (circles) has a lowland rural catchment. Note difference in axis scales from Fig. 6.

Unenriched swamps and fens are often those with the greatest species diversity, as discussed earlier, and the choice of species can be important. Monitoring should always be based on the most dominant species in the plot, as its response is likely to characterise the site as a whole. Fast-growing herbaceous species like *Typha* and some *Juncus* and *Carex* spp. are good choices, as they tend to respond quickly to enrichment. Woody species and species like the large tussock sedge *Carex secta* tend to be less useful because there can be considerable internal recycling of nutrients in their old tissues.

Note that correlations between soil N and P concentrations and plant N and P concentrations are usually poor within wetlands or between wetlands of the same class, because plants' nutrient uptake reflects their own nutrient requirements as well as nutrient availability.

Appendix III: Equipment Required for Field Assessment of Condition

1. Handbook or Tables 5 and 6
2. Wetland record sheet. Electronic version is available at wetlanddatabase@landcareresearch.co.nz.
3. Plot sheets (several). Electronic version available as above.
4. Aerial photos of wetland at suitable scale – coloured are best
5. Wooden, plastic, or fibre glass poles to mark permanent plots – 4 per plot
6. GPS if available and/or NZMS 260 topographic map
7. Tape measure, e.g., 20m, to delineate boundaries of plot
8. Small tape measure to measure height of species e.g., a builder’s 5-m retractable steel tape measure
9. Steel liner for taking substrate/soil cores, e.g., 7cm diameter by 10cm height
10. Knife for cutting out core – one with a serrated edge is recommended
11. Plastic bags for cores – 2 per plot
12. Permanent markers for labelling
13. Small paper bags or envelopes for foliage samples – 1 per plot
14. Field pH meter (if available)
15. Field conductivity meter (if available)
16. von Post scoring scale (Appendix VI in handbook)
17. Chilli bin, if necessary, for storage of substrate samples in the field.

Appendix IV: Case Studies from Field Trials

A: Lake Tomarata, Auckland Region:

WETLAND RECORD SHEET

Wetland name:	Lake Tomarata	**Date:**	31/01/01
Region:	Auckland	**Grid Ref.:**	R08 588548
Altitude:	20m	**No. of plots sampled:**	3

***Classification:* I System**	**IA Subsystem**	**II Wetland Class**	**IIA Wetland Form**
Palustrine	Permanent	Fen	Basin

Field team: Bev Clarkson, Paul Champion, Brian Sorrell, Trevor Partridge, Shona Myers, Sherilyn Hinton, Ngaire Sullivan

Indicator	**Indicator components**	**Specify and Comment**	**Score 0– 5[1]**	**Mean score**
Change in hydrological integrity	Impact of manmade structures	Some drainage on SE boundary, no evidence of drains in wetland	4	4
	Water table depth	Only minor changes	4	
	Dryland plant invasion	Confined to margins	4	
Change in physico-chemical parameters	Fire damage	No evidence	5	4
	Degree of sedimentation/erosion	None	5	
	Nutrient levels	Elevated in runoff-affected areas	3	
	von Post index	Central areas undecomposed	3	
Change in ecosystem intactness	Loss in area of original wetland	Main part of wetland intact. Some loss at southeast end	4	4
	Connectivity barriers	Mostly intact	4	
Change in browsing, predation and harvesting regimes	Damage by domestic or feral animals	Stock damage confined to SW margins. Feral animal access discouraged by vegetation density	4	4.25
	Introduced predator impacts on wildlife	Low, fernbirds present	4	
	Harvesting levels	None	5	
Change in dominance of native plants	Introduced plant canopy cover	Mainly confined to margins	4	4
	Introduced plant understorey cover	Mainly confined to margins	4	
Total wetland condition index /25				20.25

[1] Assign degree of modification as follows: 5=v. low/ none, 4=low, 3=medium, 2=high, 1=v. high, 0=extreme

Main vegetation types:
- raupo reedland
- manuka scrub
- *Empodisma* wirerushland

Native fauna: black-backed gull, black shag, pukeko, fernbird (heard)

Other comments: Small lake with wetland on southern side, and pine forest on duneland to north.

Pressure	Score[2]	Specify and Comment
Modifications to catchment hydrology	1	Mainly from change in vegatation cover to pasture & pines
Water quality within the catchment	2	Some runoff from farmed catchment
Animal access	3	Some fences insecure on SW margins allowing stock access
Key undesirable species	1	Some pampas in catchment
% catchment in introduced vegetation	4	Some native forest remnants, mainly pasture, pines
Other pressures	-	
Total wetland pressure index /30	11	

[2]Assign pressure scores as follows: 5=very high pressure, 4=high, 3=medium, 2=low, 1=very low, 0=none

WETLAND PLOT SHEET

Wetland name: Lake Tomarata **Date:** 31/01/01 **Plot no:** T1
Plot size (2m x 2m default)**:** $4m^2$ **Altitude:** 20m **GPS/GR:** R08 590547
Field leader: Bev Clarkson **Structure:** Scrub **Composition:** Manuka

Canopy			Subcanopy			Groundcover		
Species[1] (or Substrate)	**%**	**H**	**Species**	**%**	**H**	**Species**	**%**	**H**
Leptospermum scoparium	98	3.0				*Isachne globosa*	4	0.4
Coprosma tenuicaulis	2	2.5				*Gleichenia dicarpa*	5	0.8
						Blechnum novae-zelandiae	5	0.4
						Baumea arthrophylla	2	0.6
						L. scoparium seedlings	1	0.1

[1] % = % cover within relevant vegetation layer; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type: *Phormium tenax, Carex virgata, Baumea teretifolia, Eleocharis acuta, Paspalum distichum*, Holcus lanatus**

Comments: Narrow vegetation zone on margin of wetland and bordered by pasture

Indicator (use plot data only)	**%**	**Score 0–5**[2]	**Specify & Comment**
Canopy: % cover introduced species	0	5	
Understorey: % cover introduced spp[3]	0	5	
Total species: % number introduced spp	0	5	
Total species: overall stress/dieback	NA	5	
Total plot condition index /20	NA	20	

[2]5=0%: none, 4=1– 24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; v. high
[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm	5	Water conductivity uS (optional)	280
Water pH (optional)	5.9	von Post peat decomposition index	10 v decomposed

Soil core laboratory analysis (2 soil core subsamples)**:**

Water content % dry weight	523	Total C %	20.2
Bulk Density T/m^3	0.16	Total N %	1.16
pH	4.68	Total P mg/kg	720
Conductivity uS	Not analysed		

Foliage laboratory analysis (leaf/culm sample of dominant species):

Species	Manuka	%N	1.1	%P	0.095

WETLAND PLOT SHEET

Wetland name: Lake Tomarata
Date: 31/01/01
Plot no: T2
Plot size (2m x 2m default): $4m^2$
Altitude: 20m
GPS/GR: R08 590548
Field leader: Bev Clarkson
Structure: wirerushland
Composition: *Empodisma /Gleichenia dicarpa*

Canopy			**Subcanopy**			**Groundcover**		
Species[1] (or Substrate)	**%**	**H**	**Species**	**%**	**H**	**Species**	**%**	**H**
Empodisma minus	70	0.9				*Gleichenia dicarpa*	10	0.5
Gleichenia dicarpa	25	0.8				*Tetraria capillaris*	+	0.4
Baumea teretifolia	5	1.0				*Baumea teretifolia*	+	0.4
Schoenus brevifolius	+	1.0						
Tetraria capillaris	+	0.75						

[1]%=% cover within relevant vegetation layer; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type: *Baumea arthrophylla, Phormium tenax, Drosera binata, Leptospermum scoparium*

Comments:

Indicator (use plot data only)	**%**	**Score 0–5**[2]	**Specify & Comment**
Canopy: % cover introduced species	0	5	
Understorey: % cover introduced spp[3]	0	5	
Total species: % number introduced spp	0	5	
Total species: overall stress/dieback	NA	5	
Total plot condition index /20	NA	20	Healthy native system

[2]5=0%: none, 4=1– 24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; v. high
[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm	30	Water conductivity uS (optional)	180
Water pH (optional)	5.3	von Post peat decomposition index	2

Soil core laboratory analysis (2 soil core subsamples):

Water content % dry weight	801	Total C %	47.3
Bulk Density T/m^3	0.05	Total N %	0.91
pH	4.42	Total P mg/kg	112
Conductivity uS	Not analysed		

Foliage laboratory analysis (leaf/culm sample of dominant species):

Species	*Empodisma*	%N	0.68	%P	0.026

WETLAND PLOT SHEET

Wetland name: Lake Tomarata **Date:** 31/01/01 **Plot no:** T3
Plot size (2m x 2m default)**:** 4m^2 **Altitude:** 20m **GPS/GR:** R08 593548
Field leader: Bev Clarkson **Structure:** reedland **Composition:** raupo

Canopy			**Subcanopy**			**Groundcover**		
Species[1] (or Substrate)	**%**	**H**	**Species**	**%**	**H**	**Species**	**%**	**H**
Typha orientalis	85	3.5				*Myosotis laxa**	+	0.8
Mud/ litter	15	-				*Ludwigia palustris**	1	0.1
						Typha orientalis	10	0.2

[1]%=% cover within relevant vegetation layer; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type: *Polygonum hydropiper*, Juncus effusus*, Ranunculus repens*, Ranunculus flammula*, Persicaria decipiens*

Comments: Very dry at time of visit. Raupo is very tall and vigorous

Indicator (use plot data only)	**%**	**Score 0–5**[2]	**Specify & Comment**
Canopy: % cover introduced species	0	5	
Understorey: % cover introduced spp[3]	1	4	
Total species: % number introduced spp	66	2	
Total species: overall stress/dieback	NA	5	Healthy raupo 12 shoots/m^2, 10-11 leaves/shoot
Total plot condition index /20	NA	16	Introduced spp very minor components only

[2]5=0%: none, 4=1–24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; v. high
[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm	>20	Water conductivity uS (if present)	No water
Water pH (if present)	No water	von Post peat decomposition index	N/A

Soil core laboratory analysis (2 soil core subsamples)**:**

Water content % dry weight	164	Total C %	10.2
Bulk Density T/m^3	0.40	Total N %	0.73
pH	4.92	Total P mg/kg	896
Conductivity uS	Not analysed		

Foliage laboratory analysis (leaf/culm sample of dominant species)**:**

Species	Raupo	%N	2.69	%P	0.201

B: Awarua Bog, Southland Region:

WETLAND RECORD SHEET

Wetland name: Awarua Bog (Seaward Moss) **Date:** 1.6.01
Region: Southland **GPS:** See plots
Altitude: 1–20m **No. of plots sampled:** 4

Classification: I System	**IA Subsystem**	**II Wetland Class**	**IIA Wetland Form**
Palustrine	Permanent	Bog	Floodplain

Field team: Brian Sorrell, Trevor Partridge, Bev Clarkson, Paul Champion, Keith Hamill, Eric Edwards, Randall Milne.

Indicator	**Indicator components**	**Specify and Comment**	**Score 0– 5[1]**	**Mean score**
Change in hydrological integrity	Impact of manmade structures	Little effect at present	4	**4**
	Water table depth	Remains high in most areas	4	
	Dryland plant invasion	Confined to roadsides & margins	4	
Change in physico-chemical parameters	Fire damage	Little recent evidence		**4.5**
	Degree of sedimentation/erosion	No effect at present	5	
	Nutrient levels	Remaining low at present	5	
	von Post index	Peat in good condition overall	4	
Change in ecosystem intactness	Loss in area of original wetland	Largely still intact	4	**4.5**
	Connectivity barriers	None – due to large internal size	5	
Change in browsing, predation and harvesting regimes	Damage by domestic or feral animals	Very little	5	**4.83**
	Introduced predator impacts on wildlife	Low predator access	4	
	Harvesting levels	None	5	
Change in dominance of native plants	Introduced plant canopy cover	Few introduced plants in canopy. Restricted to margins	4	**4**
	Introduced plant understorey cover	Mainly restricted to margins	4	
Total wetland condition index /25				**21.83**

[1] Assign degree of modification as follows: 5=v. low/ none, 4=low, 3=medium, 2=high, 1=v. high, 0=extreme

Main vegetation types:

- Manuka/*Empodisma* wirerushland
- Manuka scrub
- Harakeke/*Empodisma-Baumea tenax* flaxland
- *Donatia-Oreobolus pectinatus* cushionfield
- *Sphagnum* mossland (not sampled)
- Oioi rushland (not sampled)

Important native fauna:

Polychroma (skink), Carabid beetles, slaters, fernbird, heron, pipit, black-backed gull.

Other comments:

Pressure	**Rating**[2]	**Specify and Comment**
Modifications to catchment hydrology	1	Bog hydrology isolated from most of catchment
Water quality within the catchment	1	Little effect of human activities on water quality at present
Animal access	1	Low
Key undesirable species	1	No major threats due to isolation by size
% catchment in introduced vegetation	1	Little introduced vegetation in area
Other pressures	1	Bog largely isolated from rural landuse
Total wetland condition index /30	6	

[2]Assign pressure scores as follows: 5=very high pressure, 4=high, 3=medium, 2=low, 1=very low, 0=none

WETLAND PLOT SHEET

Wetland name: Awarua Bog **Date:** 1.6.01 **Plot no:** A1
Plot size (2m x 2m default)**:** $4m^2$ **Altitude:** 10m **GPS:** E 21 59 130, N 53 97 279
Field leader: Brian Sorrell **Structure:** wirerushland **Composition:** Manuka/*Empodisma*

Canopy			**Subcanopy**			**Groundcover**		
Species[1] (or Substrate)	**%**	**H**	**Species**	**%**	**H**	**Species**	**%**	**H**
Leptospermum scoparium	15	0.81				*Sphagnum cristatum*	10	0.05
Empodisma minus	70	0.72				*Dicranum robustum*	5	0.03
Gleichenia dicarpa	10	0.61				*Cladina sp.*	+	0.03
Dracophyllum aff. *oliveri*	5	0.53				*Cyathodes empetrifolia*	1	0.1

1 % = % cover within relevant vegetation layer; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type: *Thelymitra cyanea, Sphagnum falcatulum, Gaultheria macrostigna, Pentachondra pumila, Isolepis distigmatosa, Isolepis aucklandica, Baumea rubiginosa, Coprosma* aff. *intertexta , Nertera scapanioides, Gonocarpus micranthus, Baumea tenax, Celmisia gracilenta, Blechnum novae-zealandiae (B. minus)*

Comments: Sparse, low-stature manuka in dense wire rush vegetation.

Indicator (use plot data only)	**%**	**Score 0–5**[2]	**Specify & Comment**
Canopy: % cover introduced species	0	5	
Understorey: % cover introduced spp[3]	0	5	
Total species: % number introduced spp	0	5	
Total species: overall stress/dieback	NA	5	
Total plot condition index /20	NA	20	No introduced plants or dieback

[2]5=0%: none, 4=1–24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; v. high
[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm	+1 cm	Water conductivity uS (if present)	Not recorded
Water pH (if present)	4.7	von Post peat decomposition index	2 light brown

Soil core laboratory analysis (2 soil core subsamples)**:**

Water content % dry weight	1626	Total C %	50.1
Bulk Density T/m^3	0.16	Total N %	1.02
pH	3.90	Total P mg/kg	101
Conductivity uS	Not analysed		

Foliage laboratory analysis (leaf/culm sample of dominant species):

Species	*Empodisma minus*	%N	0.83	%P	0.065

WETLAND PLOT SHEET

Wetland name: Awarua Bog **Date:** 1.6.01 **Plot no:** A2
Plot size (2m x 2m default)**:** 4m^2 **Altitude:** 14m **GPS:** E 21 59 243, N 53 97 304
Field leader: Brian Sorrell **Structure:** scrub **Composition:** Manuka

Canopy			**Subcanopy**			**Groundcover**		
Species[1] (or Substrate)	**%**	H	**Species**	**%**	**H**	**Species**	**%**	**H**
Leptospermum scoparium	100	2.3	*Cyathodes juniperina*	2	1.0	*Nertera scapanioides*	2	
			Pteridium esculentum	5	1.5	*Usnea sp.*	+	
						L. scoparium seedlings	1	0.1

1 % = % cover within relevant vegetation layer; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type: *Coprosma taylori, Coprosma aff. intertexta, Blechnum procerum, Baumea tenax, Dicranum robustum, Cladina* sp., *Cyathodes empetrifolia, Dracophyllum aff. oliveri, Empodisma minus*

Comments: Dense manuka canopy with sparse understorey

Indicator (use plot data only)	%	**Score 0–5**[2]	**Specify & Comment**
Canopy: % cover introduced species	0	5	
Understorey: % cover introduced spp[3]	0	5	
Total species: % number introduced spp	0	5	
Total species: overall stress/dieback	NA	5	
Total plot condition index /20	NA	20	No introduced plants or dieback

[2]5=0%: none, 4=1–24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; v. high
[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm	Too low to record	Water conductivity uS (if present)	Not recorded
Water pH (if present)	Not recorded	von Post peat decomposition index	7

Soil core laboratory analysis (2 soil core subsamples):

Water content % dry weight	557	Total C %	55.1
Bulk Density T/m^3	0.37	Total N %	1.53
pH	3.65	Total P mg/kg	354
Conductivity uS	Not analysed		

Foliage laboratory analysis (leaf/culm sample of dominant species):

Species	*Leptospermum scoparium*	%N	0.95	%P	0.072

WETLAND PLOT SHEET

Wetland name: Awarua Bog **Date:** 1.6.01 **Plot no:** A3
Plot size (2m x 2m default)**:** 4m^2 **Altitude:** 8m **GPS:** E 21 59 242, N 53 97 304
Field leader: Brian Sorrell **Structure:** wirerushland **Composition:** Harakeke/*Empodisma-Baumea tenax*

Canopy			**Subcanopy**			**Groundcover**		
Species[1] (or Substrate)	**%**	**H**	**Species**	**%**	**H**	**Species**	**%**	**H**
Phormium tenax	20	1.14	*Gleichenia dicarpa*	40	0.5	*Celmisia gracilenta*	+	0.04
Empodisma minus	50	0.80	*Cyathodes empetrifoli*a	4	0.3	*Centella uniflora*	+	0.03
Baumea tenax	20	0.90	**Schedonorus phoenix*	3	0.4	*Gaultheria macrostigna*	+	0.05
Pteridium esculentum	5	0.75	*Carex geminata*	5	0.5			
Chionocloa rubra ssp. *cuprea*	2	1.26	*Carex virgata*	2	0.4			
Cortaderia richardii	2	0.64						
Coprosma aff. *intertexta*	1	0.60						

1 % = % cover within relevant vegetation layer; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type: *Dracophyllum aff. oliveri, Leptospermum scoparium, *Agrostis stolonifera, Usnea* sp., **Rubus fruticosa, Coprosma propinqua, *Lycopus europaeus*

Indicator (use plot data only**)**	**%**	**Score 0–5**[2]	**Specify & Comment**
Canopy: % cover introduced species	0	5	
Understorey: % cover introduced spp[3]	3	4	Tall fescue in sub-canopy
Total species: % number introduced spp	7	4	One introduced species only
Total species: overall stress/dieback	NA	5	
Total plot condition index /20	NA	18	

[2]5=0%: none, 4=1–24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; v. high
[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm	+21 cm	Water conductivity uS (if present)	Not recorded
Water pH (if present)	5.1	von Post peat decomposition index	Not recorded

Soil core laboratory analysis (2 soil core subsamples)**:**

Water content % dry weight	1205	Total C %	46.6
Bulk Density T/m^3	0.23	Total N %	1.80
pH	3.97	Total P mg/kg	875
Conductivity uS	Not analysed		

Foliage laboratory analysis (leaf/culm sample of dominant species)**:**

Species	*Empodisma minus*	%N	1.25	%P	0.074

WETLAND PLOT SHEET

Wetland name: Awarua Bog **Date:** 1.6.01 **Plot no:** A4
Plot size (2m x 2m default)**:** 4m^2 **Altitude:** 2m **GPS/GR:** E 21 69 240, N 53 92 166
Field leader: Brian Sorrell **Structure:** cushionfield **Composition:** *Donatia-Oreobolus pectinatus*

Canopy			Subcanopy			Groundcover		
Species[1] (or Substrate)	**%**	**H**	**Species**	**%**	**H**	**Species**	**%**	**H**
Donatia novae-zelandiae	50	0.06				*Nostoc* sp.	+	0.01
Leptospermum scoparium	10	0.20				*Blechnum procerum*	2	0.05
Oreobolus pectinatus	20	0.07				*Celmisia gracilenta*	+	0.01
Dracophyllum aff. oliveri	10	0.43				*Gonocarpus micranthus*	+	0.01
Drosera spathulata	+	0.01				*Nertera balfouriana*	+	0.02
Pentachondra pumila	1	0.07				*Dicranum robustum*	1	0.02
Cyathodes empetrifolia	+	0.02				*Gentiana saxosa*	+	0.03
Pernettya macrostigma	4	0.08				Unidentified liverwort	+	0.01
Isolepis aucklandica	2	0.05						
Empodisma minus	2	0.12						

1 % = % cover within relevant vegetation layer; H = maximum height in m; indicate introduced species by *

Additional species in vicinity in same vegetation type: *Phormium tenax, Apodasmia (Leptocarpus) similis, Carex virgata, Gunnera prorepens, Luzula sp., Herpolirion novae-zelandiae, Sphagnum* sp.

Comments: Distinctive cushionfield covers small area; currently being invaded by manuka, *Empodisma,* etc.

Indicator (use plot data only)	**%**	**Score 0–5**[2]	**Specify & Comment**
Canopy: % cover introduced species	0	5	
Understorey: % cover introduced spp[3]	0	5	
Total species: % number introduced spp	0	5	
Total species: overall stress/dieback	NA	4	Some damage by seabirds – now recovering
Total plot condition index /20	NA	19	No introduced species

[2]5=0%: none, 4=1–24%: very low, 3=25–49%; low, 2=50–75%: medium, 1=76–99%: high, 0=100%; v. high
[3]Add subcanopy and groundcover % cover for introduced species

Field measurements:

Water table cm	-14 cm (*Donatia*)	Water conductivity uS (if present)	Not recorded
Water pH (if present)	4.5	von Post peat decomposition index	3

Soil core laboratory analysis (2 soil core subsamples)**:**

Water content % dry weight	779	Total C %	54.5
Bulk Density T/m^3	0.08	Total N %	0.68
pH	3.95	Total P mg/kg	267
Conductivity uS	Not analysed		

Foliage laboratory analysis (leaf/culm sample of dominant species)**:**

Species	*Donatia novaezelandiae*	%N	0.74	%P	0.107

Appendix V: The Atkinson System

The Atkinson system (Atkinson 1985) for naming and mapping vegetation is widely used in terrestrial habitats, including wetlands. It was trialed at various scales in a range of both palustrine and estuarine wetlands in Phase 1 of the co-ordinated monitoring of New Zealand wetlands project (e.g., Ward and Lambie 1999, Clarkson 1998, 1999). The system was found to capture the main features of the vegetation to facilitate delineation and mapping, and was flexible enough to accommodate different scale requirements. It was sufficiently simple and well defined to be used relatively consistently by a large number of users with varying expertise.

The Atkinson system is based on the canopy layer. This is defined as the layer of plants (or substrate) that have all or parts of their crowns exposed to the sky (i.e., birds-eye view; Fig. 1).

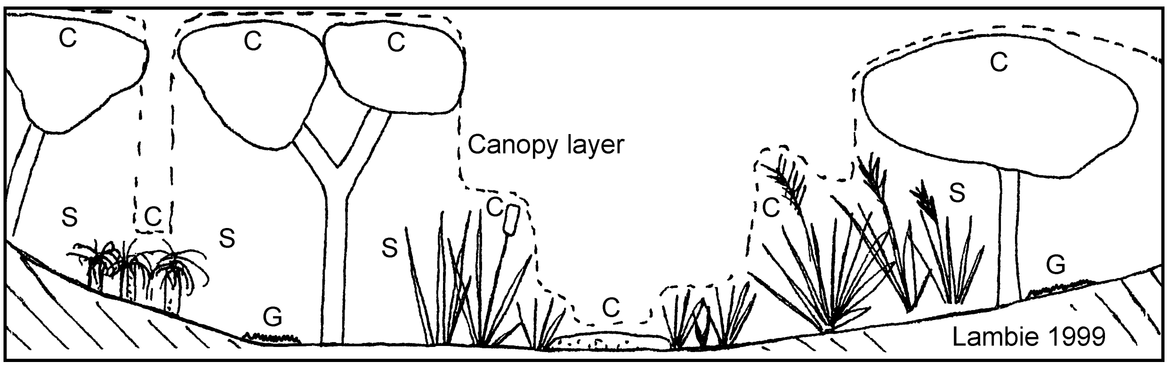

Fig. 1: Difference between canopy (C), sub-canopy (S) and groundcover (G) vegetation as determined by exposure of plants to sky. Redrawn from Ward and Lambie (1999).

An Atkinson name, e.g., *Typha* reedland, incorporates two features of the vegetation: composition and structure. The first part characterises the composition of the dominant species in the canopy (*Typha orientalis*; raupo) and the second describes the growth form (reedland). Steps in the naming procedure are:

1. Mapping or vegetation unit: Determine the vegetation boundaries according to dominant growth form (e.g., forest, scrub, sedgeland) and desired scale. This may involve using aerial photographs, high vantage points, and field reconnaissance, or marking out a plot.

2. Structural name: Allocate structural name according to the dominant growth form. The criteria for vegetation structural classes are provided in Table 1.

3. Compositional name: These are determined as follows:
   (a) Species whose cover is greater than or equal to 20%. If two or more species qualify, they are listed in order of dominance with the most dominant being first.
   (b) Where no species reaches the 20% level, the most abundant species with greater than 1% cover is used.
   (c) Where the plant cover is less than 1%, the mapping unit is named solely from the type of the ground surface, e.g., bare mud in estuarine systems is named mudfield.
   (d) If required (e.g., for monitoring invasive species), symbols may be used to denote % plant cover ranges as in Table 10 of Atkinson (1985) (species name underlined if >50%, in brackets if 10–19%, in square brackets if 1–10%).

4. Canopy height variation: Additional height information is incorporated by using a hyphen (-) for separating species of similar height, and a diagonal (/) symbol for separating species of significantly different height. For example, *Salix cinerea* / *Leptospermum scoparium* treeland indicates a mapping unit dominated by scattered grey willow (*Salix cinerea*) trees over a lower tier of manuka (*Leptospermum scoparium*) shrubs.

5. Species names: Scientific names should be used in preference to common names to ensure accuracy of the data. Both genus and species names are required except where a genus has only one species in New Zealand, e.g., *Typha* (*orientalis*), and *Empodisma* (*minus*). If common names are used, make sure the scientific name is also included elsewhere on the wetland or plot sheet.

Table 14: Diagnostic criteria for terrestrial vegetation structural classes

Structural class	**Diagnostic criteria for structural classes and definitions of growth forms**
1. FOREST	Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10cm dbh. Tree ferns ≥10cm dbh are treated as trees.
2. TREELAND	Vegetation in which the cover of trees in the canopy is 20–80%, with tree cover exceeding that of any other growth form, and in which the trees form a discontinuous upper canopy above either a lower canopy of predominantly non-woody vegetation or bare ground, e.g., mahoe/bracken treeland. (Note: Vegetation consisting of trees above shrubs is classified as either forest or scrub depending on the proportion of trees and shrubs in the canopy).
3. VINELAND	Vegetation in which the cover of *unsupported* (or artificially supported) woody vines in the canopy is 20–100%, and in which the cover of these vines exceeds that of any other growth form or bare ground. Vegetation containing woody vines that are supported by trees or shrubs is classified as forest, scrub or shrubland. Examples of woody vines occur in the genera *Actinidia* , *Clematis, Lonicera, Metrosideros, Muehlenbeckia, Ripogonum, Vitis* and others.
4. SCRUB	Woody vegetation in which the cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (cf. FOREST). Shrubs are woody plants <10cm dbh.
5. SHRUBLAND (including tussock-shrubland)	Vegetation in which the cover of shrubs in the canopy is 20–80% and in which the shrub cover exceeds that of any other growth form or bare ground. It is sometimes useful to separate tussock-shrublands as a sub-class for areas where tussocks are >–20% but less than shrubs. (Note: The term scrubland is not used in this classification).
6. TUSSOCKLAND (including flaxland*)	Vegetation in which the cover of tussocks in the canopy is 20–100%, and in which tussock cover exceeds that of any other growth form or bare ground. Tussocks include all grasses, sedges, rushes, and other herbaceious plants with linear leaves (or linear non-woody stems) that are densely clumped and >10cm height. Examples of the growth form occur in all species of *Cortaderia, Gahnia,* and *Phormium,* and in some species of *Chionochloa, Poa, Festucs, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla,* and *Celmisia.* It is sometimes useful to separate *flaxland** as a subclass for areas where species of *Phormium* are dominant.
7. FERNLAND	Vegetation in which the cover of ferns in the canopy is 20–100%, and in which the fern cover exceeds that of any other growth form or bare ground. Tree ferns ≥10cm dbh are excluded as trees (cf. FOREST).
8. GRASSLAND	Vegetation in which the cover of grass in the canopy is 20–100%, and in which the grass cover exceeds that of any other growth form or bare ground. Tussock-grasses are excluded from the grass growth-form.

* The term "flaxland" could not be used outside New Zealand because elsewhere the name flax is widely applied to species of *Linum*

Table 14 *cont*

Structural[2] class	**Diagnostic criteria for structural classes and definitions of growth forms**
9. SEDGELAND	Vegetation in which the cover of sedges in the canopy is 20–100%, and in which the sedge cover exceeds that of any other growth form or bare ground. Included in the sedge growth form are many species of *Carex, Uncinia,* and *Scirpus.* Tussock-sedges and reed-forming sedges (cf. REEDLAND) are excluded.
10. RUSHLAND	Vegetation in which the cover of rushes in the canopy is 20–100% and in which the rush cover exceeds that of any other growth form or bare ground. Included in the rush growth form are some species of *Juncus* and all species of *Sporadanthus, Leptocarpus,* and *Empodisma*[3]. Tussock-rushes are excluded.
11. REEDLAND	Vegetation in which the cover of reeds in the canopy is 20–100%, and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either hollow or have a very spongy pith. Examples include *Typha, Bolboschoenus, Scirpus lacustris, Eleocharis sphacelata,* and *Baumea articulata.*
12. CUSHIONFIELD	Vegetation in which the cover of cushion plants in the canopy is 20–100%, and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions. The growth form occurs in all species of *Donatia, Gaimardia, Hectorella, Oreobolus,* and *Phyllachne* as well as in some species of *Aciphylla, Celmisia, Centrolepis, Chionohebe, Colobanthus, Dracophyllum, Drapetes, Haastia, Leucogenes, Luzula, Myosotis, Poa, Raoulia,* and *Scleranthus.*
13. HERBFIELD	Vegetation in which the cover of herbs in the canopy is 20–100%, and in which the herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.
14. MOSSFIELD	Vegetation in which the cover of mosses in the canopy is 20–100%, and in which the moss cover exceeds that of any other growth form or bare ground.
15. LICHENFIELD	Vegetation in which the cover of lichens in the canopy is 20–100%, and in which the lichen cover exceeds that of any other growth form or bare ground.
16. ROCKLAND	Land in which the area of residual bare rock exceeds the area covered by any one class of plant growth-form. Cliff vegetation often includes rocklands. They are named from the leading plant species when plant cover ≥1%, e.g., [koromiko] rockland.
17. BOULDERFIELD	Land in which the area of unconsolidated bare boulders (>200mm diam.) exceeds the area covered by any one class of plant growth-form. Boulderfields are named from the leading plant species when plant cover ≥1%.
18. STONEFIELD/ GRAVEFIELD	Land in which the area of unconsolidated bare stones (20–200mm diam.) and/or gravel (2–20mm diam.) exceeds the area covered by any one class of plant growth-form. The appropriate name is given depending on whether stones or gravel form the greater area of ground surface. Stonefields and gravelfields are named from the leading plant species when plant cover ≥1%.
19. SANDFIELD	Land in which the area of bare sand (0.02–2mm diam.) exceeds the area covered by any one class of plant growth-form. Dune vegetation often includes sandfields that are named from the leading plant species when plant cover ≥1%.
20. LOAMFIELD/ PEATFIELD	Land in which the area of loam and/or peat exceeds the area covered by any one class of plant growth-form. The appropriate name is given depending on whether loam or peat forms the greater area of ground surface. Loamfields and peatfields are named from the leading plant species when plant cover ≥1%.

[2] Additional structural classes appropriate to wetlands may be added, e.g., mudfield
[3] The term wirerushland may be used for wetland habitats dominated by *Empodisma.*

Appendix VI: Assessment of von Post Decomposition Index

The amount of decomposition is gauged in the field by assessing the distinctness of the structure of plant remains and colour, determined by squeezing wet peat in the hand. The following standards are based on those of von Post (Clymo 1983).

1. Undecomposed: Plant structure unaltered. Yields only clear colourless water.
2. Almost undecomposed: Plant structure distinct. Yields only clear water coloured light yellow-brown.
3. Very weakly decomposed: Plant structure distinct. Yields distinctly turbid brown water; no peat substance passes between fingers, residue not mushy.
4. Weakly decomposed: plant structure distinct. Yields strongly turbid water; no peat substance passes between fingers, residue rather mushy.
5. Moderately decomposed: Plant structure still clear but becoming indistinct. Yields much turbid brown water; some peat escapes between the fingers; residue very mushy.
6. Strongly decomposed: Plant structure somewhat indistinct but clearer in the squeezed residue than in the undisturbed peat. About half the peat escapes between the fingers; residue strongly mushy.
7. Strongly decomposed: Plant structure indistinct but still recognisable. About half the peat escapes between the fingers.
8. Very strongly decomposed: Plant structures very indistinct. About two-thirds of the peat escapes between the fingers; residue consists almost entirely of resistant remnants such as root fibres and wood.
9. Almost completely decomposed: Plant structure almost unrecognisable. Almost all the peat escapes between the fingers.
10. Completely decomposed: Plant structure unrecognisable. All the peat escapes between the fingers.

Appendix VII: Glossary of Wetland Terms and Definitions

- ***Amictic*** waters have no periods of thermal stratification or mixing each year.

- ***Bog***. A wetland deriving its water supply entirely from rainfall, and therefore generally nutrient poor (oligotrophic) (cf ***Fen***). All bogs have peat (an accumulation of partially decomposed organic matter), and so are usually markedly acidic.

- ***Dominant Cover*** is used for Level IV of the classification system. Dominant cover is primarily defined by the **dominant plant species** in the vegetation.

- ***Dune Slack***. A wet area between sand dune ridges in which wetland plants occur and where the water table is close to or above the sand surface.

- ***Dystrophic*** waters have significant peat staining that inhibits or masks nutrient status.

- ***Ephemeral*** describes wetlands where the open water surface is present only temporarily (lacustrine) or seasonally or where the defining emergent wetland vegetation is only seasonally present or temporarily induced by water level change (palustrine). Ephemeral wetlands are saturated or submerged for some periods and effectively non-wetland habitat for alternate substantial periods. During dry periods species otherwise indicative of dry-land situations invade. Wetland species may be annuals that re-establish with wet periods, or may die back to under ground storage organs.

- ***Estuarine***. A wetland hydrosystem that is permanently or periodically inundated by **estuarine waters**, where **occasionally or periodically saline waters are diluted** to >0.5% by freshwater, **or freshwater is occasionally or periodically made saline**. The dominant function affecting biota is that of saline water (>0.5% salinity). A **coastal wetland semi-enclosed by land** (open, or partly obstructed, or has sporadic access to sea) is the geomorphological setting indicative of an estuarine hydrosystem. Estuarine wetlands include supra-tidal zones in which biota is strongly influenced by irregular saline/freshwater inundation, lagoonal areas where tidal influences are restricted to periodic incursion of saline water, and dune swale areas where ground water sources are periodically supplemented by saline contributions from storm-spray, storm-surge, and estuarine flood-flows.

- ***Estuary***. A partially embayed coastal system that receives both sea water and freshwaters in a zone of mixing in a tidal regime. The tidal regime is frequently modified by river flows or bars restricting sea-water inputs or outputs, but there is always continuity of connection to the sea. Distinguished from the open coast by its protection.

- ***Eutrophic*** waters and wetlands have high nutrient status.

- ***Fen***. A wetland receiving water from rain with some ground water seepage or surface run-off carrying dissolved nutrient and organic matter (cf ***Bog***). The nutrient status of fens therefore is poor to medium (oligotrophic to mesotrophic). Fens also have peat.

- ***Flashy*** describes riverine flows that allow development of little more than microalgal felts.

- ***Flush.*** A wetland on a slope that carries moving surface water from a higher level either continuously or occasionally (cf ***Seep***).

- ***Geothermal***. A wetland hydrosystem where the dominant function is **geothermally heated water**. The RMA91 specifies geothermal waters as those heated by natural phenomena to 30 degrees C or above. Geothermal wetlands may have water temperatures below this, but must be considered geothermal due to the chemical composition of the water. Geothermal wetlands are permanently or intermittently wet areas, shallow water, or land water margins that support a natural ecosystem of plants that have compositional, structural, and/or growth rate characteristics determined by current or former inputs of geothermally-derived water.

- ***Hydroperiod.*** The frequency and duration of inundation or saturation of an ecosystem. In the context of wetland habitats, the term describes the seasonal pattern of the water level of a wetland.

- ***Hydrophyte***. Any plant that grows in water or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content; plants typically found in wet habitats.

- ***Hydrosystems*** (classification Level I) are wetland ecosystems differentiated by their broad hydrological setting, and by water salinity and temperature. In systems where wetlands comprise biota that is indicative of a mixture of hydrological and salinity regimes, the system is allocated by its dominant hydrosystem type.

- ***Intermittent*** wetlands have irregular fluctuations in water level or water table.

- ***Intertidal.*** This comprises the foreshore area exposed to air between the high and low tides, and includes the overlying waters. It includes vegetated and non-vegetated wetland classes.

- ***Lacustrine***. A wetland hydrosystem including permanent or intermittent **standing open water** in topographic depression or dammed river channel and the beds of lakes, ponds, and pools so formed. The dominant function is that of **freshwater**, with low salinity (<0.5%) if tidal. Lacustrine wetlands exclude significant (mappable) areas of water with emergent vegetation (cf ***Palustrine***) or areas where water moves at speed (cf ***Riverine***). Present definitions do not define minimum depth. The boundary between ***Palustrine*** and ***Lacustrine*** systems by definition is where vegetation is not emergent over water.

- ***Lagoon.*** A completely enclosed saline body of water that may have occasional connections to the sea. Water level fluctuations occur, but are not tidal. Sea-water inputs are irregular, and fluctuations in level tend to be long period, and often seasonal. Evaporation often plays an important role in modifying salinity patterns.

- ***Lowland*** wetlands have a low gradient with slow runs and pools, and are close to the sea.

- ***Marine***. A Wetland hydrosystem including **saline open waters, seabed, and foreshore**. The dominant function is that of saline (>0.5% salinity) water. Marine wetlands are bounded by the landward limit of tidal inundation and splash, or seaward limit of other hydrosystems (particularly ***Estuarine***). Marine includes shallow coastal waters to 6-m depth and coral reef systems to any depth. For the purposes of this classification marine wetlands include the littoral zone (photic zone to depth limit of rooted plants), intertidal, and supra-tidal zones.

- ***Marsh***. A mineral wetland that may have a peat component that is periodically inundated by standing water or slowly moving water. Water levels may fluctuate markedly (cf ***Swamp***). Marshes are usually moderate to highly nutrient rich (mesotrophic to eutrophic).

- ***Mesotrophic*** waters and wetlands have moderate nutrient status.

- ***Midland*** systems have overall flows that have a moderate gradient, and are dominated by runs/riffles.

- ***Monomictic*** lacustrine waters have single periods of thermal stratification and mixing each year.

- ***Nontidal.*** This comprises coastal areas that contain open water of variable salinity in which the water level usually changes not with diurnal tidal fluctuations but in response to irregular climatically induced events such as barrier breaches and floods. It includes lagoons and dune swale impoundments.

- ***Oligotrophic*** waters and wetlands have low nutrient status.

- ***Palustrine***. A wetland hydrosystem including lands bound by dry land or by any other hydrosystem, where attached/rooted **vegetation is emergent** (cf ***Riverine*** or ***Lacustrine***) permanently or seasonally above **freshwater** (<0.5% salinity), non-tidal surface water or groundwater. Palustrine wetlands include marsh, bog, swamps, fens, bog, marshes, seeps and flushes. Palustrine wetlands exclude wetlands influenced by saline water such as saltmarsh.

- ***Perennial*** riverine systems include permanently flowing waters in channels, even where parts of a flow are below a porous channel surface.

- ***Permanent*** wetlands have a water level or watertable that is constantly high, and the defining vegetation persists throughout the year. In extreme dry periods, plant community composition may change, but species are identifiable to wetlands (cf ***seasonal***, ***ephemeral*** and ***intermittent***).

- ***Plutonic.*** A wetland hydrosystem that includes all underground water-bodies where light level are too low to permit photosynthetic activity, and hence plant production. Biotic communities include fungi, microbes, meiofauna, insect larvae, and/or some fish species. Plutonic wetlands include underground pools and streams from karst and volcanic strata, and aquifers.

- ***Polymictic*** waters have several periods of thermal stratification and mixing each year.

- ***Riverine***. A wetland hydrosystem where the dominant function is **continually or intermittently flowing open fresh water**. Includes natural and modified streams and rivers, creeks, canals and channels and the beds so formed. Riverine wetlands exclude significant (mappable) areas of emergent vegetation (cf ***Palustrine***), even where these are emergent over running water. Riverine wetlands are bounded by their downstream limit by ***Estuarine*** hydrosystems which contain a saline influence.

- ***Saltmarsh*** consists of vegetation of land-based physiology that is tolerant of salt, and the absence of species that are not salt tolerant.

- ***Seagrass meadows*** are within the tidal zone and are dominated by *Zostera*, a marine (aquatic physiology) flowering plant intolerant of long exposure.

- ***Seasonal.*** Water level, water input, and / or waterlogging vary with seasonal events such as spring snow melt or autumn drought (cf ***permanent***, ***ephemeral*** and ***intermittent***).

- ***Seep*** describes a wetland where water percolates to the soil surface (cf ***Flush***), with a flow being less than would be considered as a ***Spring***.

- ***Stable*** flow allows attached macrophytes and mosses to persist from year to year.

- ***Spring***. A stream emerging to the surface from underground. Usually of considerable flow, without emergent vegetation where the spring emerges from the ground (cf ***Flush*** and ***Seep***).

- ***Steepland*** has overall flows that are high gradient, well aerated with broken surfaces.

- ***Structural class*** is primarily defined by the **structure/physiognomy** of the dominant canopy vegetation (classification Level III). These terms have been described in Atkinson (1985) not in ref list and include such common terms as forest, shrubland, grassland, sedgeland, tussockland etc. In response to the issue of identification of certain of these in the wetland situation, flexibility is allowed, with the compositional descriptors providing the appropriate comparisons where there is confusion.

- ***Sub-systems*** are primarily defined by **flooding regime** (hydro-periodicity) and are used to describe wetlands at Level IA in the classification.

- ***Subtidal.*** This comprises areas permanently inundated with marine or estuarine waters. It includes vegetated and unvegetated wetlands. Within the estuarine hydrosystem the intertidal is defined here to include the supratidal because of the difficulties of delineating the actual boundary on the ground.

- ***Supratidal.*** This comprises areas above the high water mark that are strongly influenced by periodic incursions of saline water or spray. It includes the splash zone and areas inundated by storm surges.

- ***Swamp.*** A wetland where water supply is augmented by ground-water seepage or surface run-off that has been in contact with mineral materials in adjacent land, and carries inputs of dissolved nutrients and often also suspended inorganic sediment. Swamps usually have a combination of mineral and peat substrates. Leads of standing water or surface channels with gentle permanent or periodic internal flow may be present (cf ***Marsh***). Swamps are relatively rich in nutrients (mesotrophic to eutrophic) and the watertable is usually permanently above some of the ground surface, or periodically above much of it.

- ***Tidal.*** Wetlands where the water level regime is determined by the diurnal rise and fall of tidal saline waters. Tides can have upstream effects above saline inputs, but where the salinity falls below 0.5%, or where the vegetation is characteristic of freshwater conditions, the boundary with the palustrine system occurs. The extent of the wetland may be above the full tidal range (Mean High and Low Water Spring are often used as definitions), but seldom below.

- ***Variable*** flow is one that allows development and scouring of macroalgae.

- ***Watertable*** defines the water level relative to the ground surface, i.e. the level below which is fully saturated. Also commonly applied to road ditches in New Zealand.

- ***Wetland***. The RM Act (1991) defines wetlands as "permanently or intermittently wet areas, shallow water or land/water margins that support a natural ecosystem of plants and animals that are adapted to living in wet conditions". They may be saline, freshwater, or brackish. Wetlands have internal interactions between water regime, chemistry, soils, vegetation and fauna that define them, and have a boundary beyond which external interactions are either inputs or outputs.

- ***Wetland Class*** is used in the classification system (Level II) and comprises distinct kinds of vegetation in which characteristic **functional** features other than those of hydrology dominate to such an extent that they cause major vegetation patterns. These include substrate, acidity and chemistry. For instance, acidity and chemistry are important for defining different types of palustrine system, while chemistry, especially in relation to salinity, helps define estuarine wetland classes.

- ***Wetland Form*** is primarily defined by **landform** (hydrogeomorphic setting) and is used to classify wetlands at level IIA.