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Cover: Wetlands bordering Mahinapua Creek, Westland. The stream contains submerged aquatic plants and the floating foliage of water lily. Turf on the stream margin grades back to flax swamp then kahikatea forest swamp.

Inside covers: Map of New Zealand showing major localities and regions.

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ONE

Introduction

Wetlands are precisely that: wet lands. They are places of poor drainage or where water accumulates; sites where seepage or flooding is frequent; interfaces where land meets streams, rivers, lakes, and estuaries. Wetlands grade to aquatic habitats of deep water. Freshwater wetlands grade to brackish or saline wetlands of coastal estuaries and the sea itself. All forms of life need water, but wetland plants and animals are adapted to cope with an oversupply of wetness, and its consequences, such as nutrient shortages and the need to ensure a supply of oxygen to underwater parts. Each wetland organism lives in those particular places that match its own requirements, tolerances, and competitive ability. Some plant species are restricted to wetlands (obligate wetland plants), while others range also to dryland habitats (facultative wetland plants). Wetlands are diverse for many reasons, and New Zealand has many different sorts.

A definition of wetland for New Zealand purposes is provided in the Resource Management Act (1991): '"Wetland" includes permanently or intermittently wet areas, shallow water, and land water margins that support a natural ecosystem of plants and animals that are adapted to wet conditions.'

A wider definition of wetlands is provided by the Ramsar Convention on Wetlands, signed in Ramsar, Iran, in 1971, as an intergovernmental treaty to which New Zealand is a contracting party: 'For the purpose of this Convention wetlands are areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.'

Classification of wetlands helps with the recognition of wetland types, so that each can be better understood, managed, and monitored. Although it is desirable to classify things into neatly defined boxes, wetlands do not make this easy for us. This is because wetlands vary along gradients of many environmental factors – such as dryness to wetness, infertile to fertile, acid to basic, fresh to saline – and although we may insightfully recognise many wetland types, the boundaries between them are not distinct realities of any natural laws of ecology.

Recognising wetlands and delimiting their boundaries on the ground can be tricky for several reasons. Wetland sites visible on the land surface are functionally connected to larger areas of water catchment and to an unseen extent of groundwater. Some wetlands can go unrecognised because they dry out in summer. Vegetation and plants typical of wetlands may extend onto relatively dry lands that have very infertile soils. And although the laying down of peat is correctly associated with many wetlands, there are also extensive peatlands that cannot be wholly regarded as wetlands.

Different sorts of wetlands result from their diversity of landform settings, origins, substrates, hydrology, nutrient status, and vegetation. A classification system may emphasise any one of these factors, but must be flexible enough in its application to recognise that wetland types grade into each other, and that wetlands are dynamic systems that change over time. Difficulties also arise with the names used for wetland categories because most terms have originated overseas where they have been defined and applied in sometimes conflicting ways. The current treatment represents one more step in the long-standing and difficult process of defining terms and using names in ways that suit New Zealand needs, while retaining some equivalence with international concepts.

In less than two centuries New Zealand wetlands have been severely reduced in extent: the figure of 10% is often quoted (unchallenged) for the area that now remains. The numerous values and uses of wetlands have been well documented and are not detailed again here. Suffice it to note that healthy wetlands are part of a healthy environment; yet wetlands continue to be lost, degraded, undervalued, ignored, and destroyed both deliberately and through ignorance. By being able to recognise wetland ecosystems, types, and features we are in a position to understand wetland functioning and processes. These in turn assist with the necessary business of wetland inventory, mapping, survey, and the monitoring of condition and extent, all of which are needed for protecting, managing, and enhancing our wetlands.

Every wetland visitor or researcher must expect a challenge in trying to work out how a wetland functions, and what type to call it. Future studies will allow for more watertight definitions and assessment of wetland types and features, as well as recognising new types. Until such time, be aware that even professional and experienced wetland ecologists spend much time arguing, disagreeing, and speculating about how any wetland system or site works. Wetlands do not reveal their secrets readily!

This book results from one of several goals of a Ministry for the Environment project on coordinated monitoring of New Zealand wetlands (Ward & Lambie 1998, 1999a,b; Downs et al. 2001; Harmsworth 2002; Clarkson et al. 2003). Our project has sought to develop a coordinated approach and standardised eco-classification to facilitate international reporting under the Ramsar Convention on Wetlands and national state-of-the-environment reporting under the Resource Management Act on changes in wetland extent and condition. One aspect of the project has been to develop a wetland classification system that is based primarily on wetland function (Gerbeaux & Richmond 1999; Partridge et al. 1999). This system allows for wetlands to be recognised at several sequential levels of a hierarchy, from broadly defined hydrosystems, to wetland classes, then structural classes of vegetation, and finally wetland 'types' distinguished by their composition of dominant plants. It should be noted that since Ward & Lambie (1999b) outlined this classification framework we have become aware of some inconsistencies and have sought to correct these and refine the circumscriptions of some wetland classes; these changes are noted in Section 2.2.

The emphasis of this book is on inland freshwater wetlands, those near coastal estuaries, and those of lake and river margins. Fully aquatic systems of lakes and rivers are covered in much less detail, these topics having their own complexity of literature in hydrology and limnology (e.g. Irwin 1975b). A draft structure for classification of geothermal and plutonic hydrosystems is set out as table 3 of Ward & Lambie (1999b) and of marine, lacustrine, and riverine hydrosystems in their table 4. An alternative classification of wetlands of all types was adopted by contracting parties to the Ramsar Convention in 1990, and although available on the Ramsar website, is currently under review.

Our main purpose is to describe and illustrate how wetland types can be recognised and named. Section 2 deals with the classification system, noting some of the background to wetland classification, and then describing the classification tiers. Section 3 demonstrates patterns in wetlands and shows how the classification system can be applied to them. Section 4 describes how wetlands function, especially in relation to the variables of hydrology, nutrients, and substrates, and discusses how wetlands change over time. Section 5 provides some direction on wetland survey methods, use of the classification system, and a guide to further information. A glossary of terms is provided at the end.

TWO

The classification system

2.1 Background to wetland types, terms, and classification

Systems for arranging types of New Zealand wetlands have variously given primary emphasis to vegetation, landforms, or substrates. Most wetland terms have come from other countries and have gradually been adopted here in both common and ecological usage. As an example, common parlance and the coining of place names for New Zealand wetlands often use the words bog and swamp almost interchangeably, whereas ecologists make a clear distinction between them: bogs are at the infertile end, while swamps are at the fertile end of a nutrient gradient in wetlands.

The pioneer plant ecologist Leonard Cockayne described New Zealand wetlands under headings of landform settings and vegetation, grouping most wetland types into the categories bog and swamp, but noting also the many transitions between these, and the gradations that occur between wetland and dryland, for example with his 'semi-swamp forest' (Cockayne 1928). For various forms of herbaceous wetlands he provides terms such as 'salt-meadow' (for estuarine sites), 'coastal-moor' (for coastal slopes), and 'herb-moor' (for upland sites).

The classification by Cranwell (1953) concentrates on peat types, their mode of deposition, topographic setting, the forms they create, and their general fertility. Her classification includes recognition in New Zealand of fens (in the sense used in the United Kingdom) as sedgy and woody vegetation on nearly neutral or only slightly acid substrates: i.e. something between bog and swamp.

In describing wetlands of Canterbury, South Island, uplands, Burrows (1969) describes flushes as distinct from bogs, as being sites that receive water and nutrients from upslope, and he recognises several types, such as 'wet flush', 'seepage flush', 'herb flush', and 'spring head flush'. In addition, Burrows distinguishes marshes as a further group of wetlands, distinctive in their substrate and vegetation.

The term mire has been increasingly used in New Zealand, mainly as a broad term that is more or less synonymous with 'peatland' (Thompson 1987), though there has also been a tendency to apply the term to a broader category of vegetated wetlands (e.g. Burrows 1990). Dobson (1979), describing mire types of New Zealand, provides a useful outline of wetland environmental factors, and a breakdown of types based mainly on floristics, with informative diagrams relating principal plant species to soil nutrient status, temperature, and pH.

In her overview of the mires of Australasia, Campbell (1983) also emphasises the dominant plants and vegetation structure. She recognises the category of fen as including several wet grassland and sedgeland communities, and also short alpine herbfield of snow patches. Recent studies of New Zealand wetlands (e.g. McQueen & Wilson 2000) have increasingly supported the recognition of fens as distinct from bogs. Campbell (1983) uses the term 'soak' for sloping seeps in mountain lands, and introduces to New Zealand the term 'wet heath', previously used in Australia.

Wardle (1991) gives further formality to the term wet heath for the traditionally difficult-to-categorise pakihi and gumland types that occur on ultra-infertile, impervious soils, these being at the wet end of a more general, sometimes dryland, category of heathland (having vegetation of stunted, small-leaved woody plants, wiry sedges, and ferns). Although Wardle does not use the term fen, his 'infertile swamp' is an equivalent.

Thompson (1987) notes that classification of wetland types may be based upon topography, floristics, substrate types, or nutrient status, but 'in practice, it is helpful to use all four methods'. Thompson outlines different concepts of wetland and peatland, and the factors of water supply, nutrient status, peat deposition, climate, and landform that influence the range of freshwater wetland types in New Zealand. He comments on the confused terminology within peatland literature, establishes some definitions, and discusses how overseas terms might be applicable to New Zealand situations, yet without necessarily recommending their adoption (Thompson in Davoren et al. 1978; Thompson 1987).

Whereas most New Zealand accounts of wetland vegetation types (e.g. Cockayne 1928; Cranwell 1953; Dobson 1979; Campbell 1983; Johnson & Brooke 1998; Wardle 1991) have been pragmatically descriptive and not overly concerned with producing a formal and definitive classification, a few attempts at a hierarchical classification have been made, but also with an element of tentativeness. At the 1974 New Zealand Ecological Society conference, Colin Burrows presented a tabulated preliminary classification of wetlands, and although not published in that form, his classification scheme was the principal contribution to that outlined by Keith Thompson in Stephenson et al. (1983), which classified wetlands according to these tiers of factors: fresh cf. salt waters; broad landform setting; nutrient status and wetland form; and vegetation structure. Stephenson et al. (1983) cautiously include fen in their classification scheme for New Zealand, and note the term marsh as having a particular meaning: 'usually shallow water, often seasonal, mineral substrate, herbaceous vegetation'. This concept of marsh is more akin to the sense in which it has been used in Britain, rather than in the American emphasis upon habitats having plants emergent from shallow water. The European term carr has sometimes been used in New Zealand for fens dominated by woody vegetation (Sykes et al 1991).

It should be noted that although some northern hemisphere definitions of the terms bog, fen, swamp, and marsh include vegetation as a descriptive element, this is not the case in the current New Zealand classification exercise. Hence concepts such as a fen being bryophyte-dominated (Canada: Zoltai & Vitt 1995) or swamps being tree- or shrub-dominated (United States and Europe: Mitsch & Gosselink 2000) are not included here at the wetland class level.

We wish to emphasise the fact that classification is a conceptual exercise (Colin Webb, pers. comm.). As such, the number and scope of units chosen for recognition is to a large extent arbitrary. The units are not necessarily equal. They may be characterised by different properties of their overall nature, and not all properties need to carry the same weight. In relation to wetland classification it is important to realise that wetland units cannot be easily and rigidly defined. This is especially the case with wetland classes. Our approach is one of descriptively circumscribing the units so as to capture the essence of their distinctiveness.

2.2 Structure of the classification system

The wetland classification we are working with is based on that outlined by Ward & Lambie (1999b) and adopted by Clarkson et al. (2003), but with some modifications, as noted below.

Its overall structure emphasises functional aspects of wetlands, starting with the broad hydrological and landform setting, moving down to wetland classes based on substrate, water regime, and chemistry, and finally to the lowermost levels where vegetation becomes a defining factor. This method of classification is a 'top-down' one, starting at the highest level then allocating units to categories within defined levels lower in the hierarchy. Hence it is not a taxonomic or 'bottom-up' approach, which would start with recognised and named units at the finest scale, then link these by the similarities they share at whatever level. Whereas in an ideal hierarchical classification one could draw clear lines of linkage up and down the tree, and all units would be distinct from each other, this system should be regarded as semi-hierarchical, insofar as combinations of parameters are used for the groupings, both within and between levels (Gerbeaux & Richmond 1999; Partridge et al. 1999).

The six classification levels of increasing detail are outlined in Table 1. These classification levels and their units are further described in the following chapters. Although Table 1 attempts to show a neat separation between the units of hydrosystem and wetland class, the reality is that in each case there is considerable overlap between units, as shown conceptually in Figs 1 and 2.

Level I comprises nine hydrosystems, based upon broad hydrological and landform setting, salinity, and extremes of temperature. The four most important hydrosystems are estuarine, riverine, lacustrine, and palustrine. In practical terms, hydrosystems are of relevance for grouping wetlands over relatively large areas and on a regional basis. Hydrosystem boundaries cannot be expected to be clearly definable on the ground. Note that our definitions of hydrosystems differ from those in Ward & Lambie (1999b). We find their inclusion of emergent vegetation as one of the defining factors to be in conflict with the principle that hydrosystems should be based upon broad factors of hydrology and landform setting.

Level IA (subsystem) is a less formal, descriptive level, allowing for attention to be drawn to descriptors of water regime additional to those which contribute to the formulation of the wetland classes which follow.

Table 1 Outline of semi-hierarchical classification system for New Zealand wetlands

I. HYDROSYSTEM

(Based on broad hydrological and landform setting, salinity, temperature)

Marine	Estuarine	Riverine	Lacustrine	Palustrine	Inland saline	Plutonic	Geothermal	Nival

IA. SUBSYSTEM

(A descriptive level relating to water regime)

II. WETLAND CLASS

(Based on substrate, water regime, nutrients, pH)

Bog	Fen	Swamp	Marsh	Seepage	Shallow water	Ephemeral wetland	Pakihi and gumland	Saltmarsh

IIA. WETLAND FORM

- Landforms which wetlands occupy (e.g. slope, basin)
- Forms which wetlands create (e.g. domed bog, string fen)
- Forms or features which wetlands contain (e.g. pool, rand)

III. STRUCTURAL CLASS

- Structure of the vegetation (e.g. forest, rushland, herbfield), or:
- Predominant ground surface (e.g. rockfield, mudflat)

IV. COMPOSITION OF VEGETATION

- One or more dominant plants (e.g. bog pine, wire rush)

Fig. 1 A conceptual arrangement of hydrosystems in relation to 'wetland' as represented by the shaded circle.

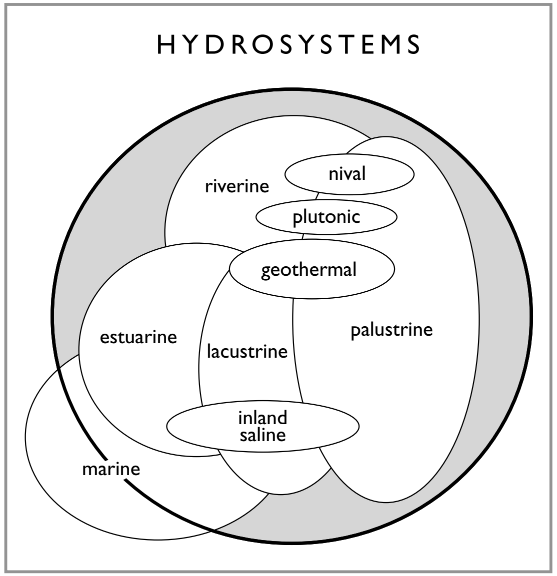
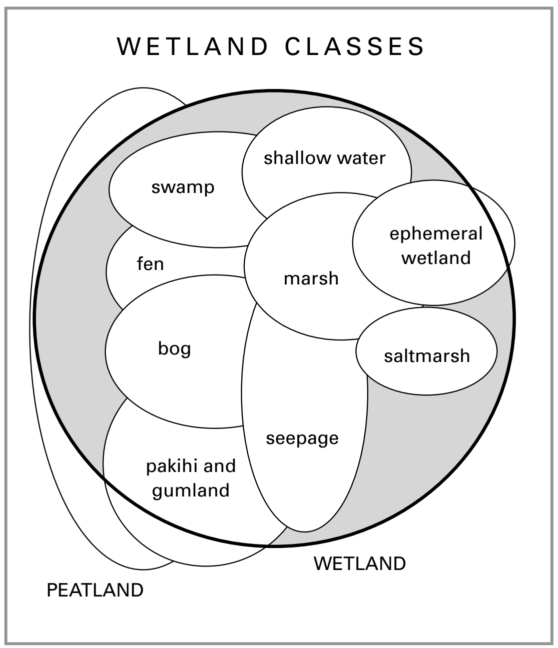


Fig. 2 A conceptual arrangement of wetland classes, their relationship to 'peatland' and to 'wetland' as represented by the shaded circle.



Level II comprises the nine wetland classes which are the units of central importance in mapping and documenting wetlands. Wetland classes may belong to one or more hydrosystems. Wetland classes are circumscribed by distinctive combinations of substrate factors, water regime, and consequent factors of nutrient status and pH (Table 2 on p. 38).

Note that we recognise three wetland classes additional to those listed by Ward & Lambie (1999b): shallow water, ephemeral wetland, and pakihi and gumland. We have adopted the wetland class term seepage to embrace 'seep' and 'flush', and regard saltmarsh as a class embracing most estuarine habitats.

Level IIA, wetland form, is a subsidiary set of descriptors of landforms which wetlands occupy, and forms that they create or contain.

Level III, structural class, is concerned with the general growth form or structure of the vegetation, or else the leading type of ground surface.

Level IV, composition of vegetation, is the lowermost level of the classification, allowing wetland types to be named from one or more of the dominant plants, in combination with a structural class.

2.3 Hydrosystems

Hydrosystems are the units of the uppermost level of wetland classification. They are based on general landform and broad hydrological settings, and distinctive features of water salinity, water chemistry, and temperature.

Nine hydrosystems are recognised. The four major ones are for wetlands associated with land, rivers, lakes, and coasts. Five minor hydrosystems accommodate habitats that are more specialised or localised, or of less relevance to the freshwater wetland theme: the open sea, inland salty places, underground, heated waters, and frozen habitats. The hydrosystems are described below in no particular order.

Because hydrosystems are a high category of classification, with very broadly circumscribed units, their practical application is most relevant for mapping at a coarse level and in grouping wetlands on a regional basis, across relatively large areas. At a detailed level of mapping it is often not possible to precisely demarcate boundaries between hydrosystems; this task becomes more practicable with the finer categories of wetland class. In wetland complexes that embrace a mixture of hydrosystems, the overall system is allocated by its dominant hydrosystem type. Examples of hydrosystems are shown in Sections 3.1 and 3.2.

2.3.1 Palustrine

All freshwater wetlands fed by rain, groundwater, or surface water, but not directly associated with estuaries, lakes, or rivers. The term palustrine derives from the Latin, *palus* = marsh. Most wetlands are palustrine, and it is this hydrosystem that includes the greatest range of wetland classes and vegetation types.

2.3.2 Riverine

Wetlands associated with rivers, streams, and other channels, where the dominant function is continually or intermittently flowing freshwater in open channels. The riverine hydrosystem includes open flowing waters and both the beds and margins (riparian zones) of channels. It embraces natural waterways and artificial ones such as canals, irrigation channels, and drains. Although many wetlands occupy landforms such as valley floors, floodplains, and deltas which owe their genesis to river processes, the riverine hydrosystem extends only so far as flowing channels retain a current influence, which can be defined as the extent covered by the mean annual flood. Towards its downstream end the riverine hydrosystem meets tidal influence and merges with the estuarine hydrosystem. The boundary can be defined as the place where estuarine salinity is 5‰ (5 parts per thousand).

2.3.3 Lacustrine

Wetlands associated with the waters, beds, and immediate margins of lakes and other bodies of open, predominantly freshwater which are large enough to be influenced by characteristic lake features and processes such as fluctuating water level, wave action, and usually permanent and often deep water that has nil or only slow flow. Lakes can be arbitrarily defined as having a major dimension of 0.5 km or more (Irwin 1975a; and see discussion in Section 2.6.3).

Fig. 3 Palustrine hydrosystem: wetlands occupying former outwash channels, Kennedys Creek, Westland.

Fig. 4 Riverine hydrosystem: flood-prone alluvium with toetoe (*Cortaderia richardii*) tussockland, Pyke River, Fiordland.

2.3.4 Estuarine

This hydrosystem embraces estuaries themselves, tidal reaches and mouths of coastal rivers, coastal lagoons, and wet habitats of open coasts where soil water is affected by sea salts. The dominant functions are the mixing of freshwater and seawater, and tidal fluctuation, both of which vary depending on degrees of direct access to the sea. The inland limit of the estuarine hydrosystem lies where salinity reaches a dilution of 5‰ marine salt concentration (Clarkson et al. 2003). The estuarine hydrosystem includes all areas of subtidal and intertidal zones in estuaries, and also wet ground in supratidal zones where surface water and groundwater receive saline contributions from wave splash, or airborne salt in sea spray; habitats which might otherwise be broadly termed coastal wetlands.

2.3.5 Marine

The saline waters of the open sea; this hydrosystem is not further considered in this book.

2.3.6 Inland saline

Inland sites in semi-arid climates where strong evaporation processes result in high concentrations of soluble salts in soil and groundwater, and where localised wetlands occur as seepages or in depressions; a minor hydrosystem in New Zealand, found mainly in the basins of inland Otago.

2.3.7 Plutonic

The plutonic hydrosystem includes all underground waterways and water bodies where light levels are too low to permit photosynthetic activity, and hence plant production, but where other inputs of energy allow for communities of fungi, microbes, insect larvae, and some fish species. Plutonic wetlands occur mainly as caves and underground streams in karst terrain (limestone and marble), but also as caves in volcanic lava, and as aquifers. Details of this hydrosystem are not further considered in this book.

Fig. 5 Lacustrine hydrosystem: wave action upon lake margin turf, Lake Wanaka, Otago.

Fig. 6 Estuarine hydrosystem: zones of seagrass (*Zostera novazelandica*), sedgeland, and rushland saltmarsh, abutting onto palustrine flaxland, Whanganui Inlet, Nelson.

Fig. 7 Marine hydrosystem: surge through kelp beds, Catlins coast, Otago.

Fig. 8 Inland saline hydrosystem: a partly dried salt pan, Maniototo basin, Otago.

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Fig. 9 Plutonic hydrosystem: represented here by a stream exit from a limestone cave, Oparara, Buller.

Fig. 10 Geothermal hydrosystem: a steamy fumarole as a stream source, Waimangu Stream, Rotorua.